MANAGEMENT of

TRAIN OPERATION and TRAIN HANDLING

Management Of Train Operation and Train Handling

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The Air Brake Association

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FOREWORD

The response to the need for a practical handbook on train operation resulted in "Modern Freight Train Handling." Brought out in 1967, this volume was the result of 2 years of work by the Editorial Committee of the Air Brake Association.

It was soon realized that a simple compiling of air brake rules from various railroads and manufacturers was not enough. A much broader base was required in order to provide answers to and guidance for the many other important interrelated factors underlying safe, practical and expeditious handling of modern freight trains. The basic "whys," "wherefores," and "whats" of locomotive operation needed to be displayed along with explanations of just what makes a train go, stop, act and react as it does. Train and locomotive air brake action needed to be integrated with dynamic brake and power. Beyond this, practical methods of handling the speed control of modern trains needed to be described and illustrated for both level and grade operations.

As can be appreciated this was a formidable job. Within the time available, we felt we could only attack one important phase of railroading —that of freight train operation. That this effort has proven useful and worthwhile is attested by the broad acceptance of the 1967 "Modern Freight Train Handling" book and the necessity of a reprint in 1969.

Changes and improvements in railroading and equipment continue to be made each year.

Recognizing the time involved, the Executive Committee of the Association at the 1969 Convention felt that we should get started on up dating and modernizing the 1967 edition. Since a basic book was in existence, we were asked to expand it to cover passenger train operations which continue to be heavy in a number of areas. Many of these include new and advanced equipment and techniques.

Specifically our thanks are extended to:
Burlington Northern
Canadian Pacific Railway Co.
Chesapeake & Ohio - Baltimore & Ohio Ry.
Electro Motive Division-GMC
General Electric Co.
Griffin Steel Foundries, Ltd.
New York Air Brake Co.
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MANAGEMENT OF TRAIN OPERATIONS

Actually, the interrelation of all of the brake, power and train response factors require a broadening of the old terminology known for years under the general term "train handling." In reality the function of running a train, keeping it on schedule and properly spaced from preceding or opposing trains is better termed "management of train operation." Years ago the term "management" referred only to the upper levels of executives extending down only about as far as the general manager.

Several departments of the railroad have specific and unique management functions in respect to train operation. The general manager and his staff usually provides overall supervision and coordination for all of the departments who have to do with providing the direct transportation services.

Although often a separate departmental function, traffic has responsibilities in this area since they generate new and different demands for shipment of various kinds of lading. Often this is in:

Larger quantities requiring bigger or different cars.

In different packaging requiring special loading and unloading equipment or systems.

In much larger total quantities requiring different types of trains such as unit coal, ore, petroleum, chemical or grain trains.

Generally traffic is able to create new business by offering the service at lower or incentive rates. It is broadly presumed that much larger quantities of lading per car or train result in lower cost. This is usually true in some areas if terminal switching and yard work can be eliminated such as with certain unit train operations, which can logically move between a single source and a single destination. However, the general presumption that costs are automatically lower by using much bigger cars in trains may not follow. To attain this goal requires careful planning and an understanding of what train action or reaction will be in order to have reasonable assurance that the costs will be sufficiently improved to make a new service profitable.

Other departments obviously involved in train management are:

Engineering—right of way, track and structures.

Operating—Assemble and run trains over the road.

Mechanical—Provide and maintain rolling stock.

A better knowledge of train operation management can benefit:

General Managers

Superintendents

Train Masters

Road Masters

As well as those who have been traditionally involved—road foreman, locomotive engineman, master mechanics, air brake men and car men.

The term train management assumes a responsible charge of the operation. This requires planning or thinking ahead and taking action when required to avoid disruption of service. Thus train management includes not only those who schedule, dispatch and run the trains, but also all those who prepare cars and trains for road operation as well as those people responsible for condition of track signals and rolling stock.

As all of us realize, the proper physical condition of cars and locomotives contributes greatly to good, reliable trouble free train operation. Even the car man on the repair track contributes to this in prompt and proper identification and repair of shortcomings or faults in air brake, and other car equipment whether caught by the car inspectors or not. The mechanic or electrician in the enginehouse similarly assists on insuring the needed supply and control of power, air and dynamic brake horsepower. These people contribute vital building blocks for making the train operation possible. The only thing railroads have to offer, is transportation service to the public moving blocks of cars in trains.

Inasmuch as the braking ability of trains is the cornerstone for safe operation, it is important to provide supervisory and operating and mechanical personnel with a solid practical knowledge of brake system operation and maintenance. The air brake supervisor and the air brake department can provide for maximizing the operating capacity of any railroad.

"MANAGEMENT OF TRAIN OPERATION AND TRAIN HANDLING"

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CHAPTER I — DEFINITIONS

AAR (abbr. for Association of American Railroads)—An organization comprising most of the railroads and private car lines of North America formed to administer the collective interest of its members. The Mechanical Division, among other duties, prescribes certain physical limits of locomotives and cars to permit the interchange of such equipment among member roads and prepares standards governing the size, quality and performance of mechanical components used in interchange service.

AB Valve (Including related schedules such as ABC, ABD)—The operating device used on freight cars for charging, applying and releasing the air brakes in response to changes in brake pipe pressure.

Accelerated Emergency Release—A release feature for brake equipment whereby each car assists in recharging brake pipe by permitting emergency brake cylinder pressure to flow into brake pipe for the initial portion of the brake pipe recharge.

Accelerated Service Release—A feature designed into ABD Freight Brake Equipment which functions to assist brake pipe recharging at each car to serially transmit release rapidly through the train.

Adhesion—The coefficient of friction between the wheel and the rail for acceleration and retardation.

Air Brake—A combination of devices operated by compressed air arranged in a system and controlled manually or pneumatically by means of which the motion of a car or locomotive is retarded or arrested.

Air Brake Equipment—All of the air brake apparatus that performs the operation necessary for supplying and exhausting air to and from the brake cylinders, but not including foundation brake gear and hand brakes.

Air Brake Safety Control (Commonly called "dead man" feature)—A system of devices which automatically causes the brake to be applied when the engineman becomes incapacitated.

Air Brake System—All of the devices and parts included in making an air brake for controlling the speed and stopping a locomotive or train. It is made up of the operating devices, the pipes, hoses, fittings, and foundation brake gear.

Air Gage—An instrument for indicating air pressures. Usually expressed in pounds per square inch (psi).

Ampere—The fundamental unit in which the strength of electrical current is measured and expressed. It represents the current strength when a potential of one volt is impressed on a resistance of one ohm. Fractional current strengths may be expressed in milliamperes, each of which is one-thousandth of an ampere.

Automatic Air Brake—An arrangement of air brake equipment. Air is stored in reservoirs on cars and locomotives and an operating valve,

such as a control, distributing, AB or ABD valve causes the brakes to apply and release through changing the brake pipe pressure, whatever may be the cause, in which a reduction in the brake pipe pressure tends to cause a brake application and increasing the brake pipe pressure tends to release the brake.

Automatic Brake Valve—A manually operated device positioned by the engineman to (1) control the flow of air into the equalizing reservoir and brake pipe for charging and releasing a brake application, and (2) provide a reduction of equalizing reservoir and brake pipe pressures at a service or emergency rate of brake application.

Automatic Drain Valve—A device which automatically drains condensate from the locomotive air supply system.

Automatic Power Reduction—Provides an infinitely variable load control below full load on the lead unit of the consist. This is useful when operating under heavy wheel slip conditions on a steep grade. Usually the lead unit will clean the rails for the trailing units, therefore power reduction makes it unnecessary to reduce the throttle on all units if only the lead unit is slipping.

Automatic Slack Adjuster—An appliance for automatically adjusting brake cylinder piston travel to a predetermined length.

Automatic Split Reduction (See Split Reduction) Automatically producing a split reduction during a safety control, automatic train stop or automatic train control application.

Auxiliary Reservoir—A storage volume to receive and store air for use in applying a brake on a car or locomotive. In freight car equipment, the auxiliary reservoir and emergency reservoir are combined in one structure.

Back-up Valve—A device, either portable or permanently connected to the brake pipe, for the purpose of controlling brakes from the rear end of train.

Bleed—A term commonly used for venting of air pressure.

Brake Cylinder—A cylinder in which compressed air acts on a piston which transmits the force of the compressed air to the associated brake rigging.

Brake Cylinder Release Valve—A device for quickly releasing the air from a brake cylinder without depleting the remainder of the brake system on the car.

Brake Hanger—That part of the foundation brake gear holding the brake head or beam in position.

Brake Head—A holder attached to or a part of the brake beam which carries the detachable brake shoe.

Brake Pipe—The system of piping including branch pipes, angle cocks, cutout cocks, dirt collectors, hose and hose couplings, used for con-

necting locomotive and all cars for the passage of air to control the locomotive and car brakes.

Brake Pipe Cutout Cock or Cut-off Valve—A device used on locomotive equipped with 24-RL or 26-L brake schedule to designate provision for cutting out the charging and service function of the automatic brake valve. On the 26-C automatic brake valve, the cut-off valve also properly positions parts for passenger or freight operation. On control valves the brake pipe cutout cock isolates the control valve from the brake pipe.

Brake Pipe Gradient—A term used to express the difference between brake pipe pressure on the front end and rear end of a train.

Brake Pipe Pressure—The pressure of the air in the brake pipe expressed in pounds per square inch in the brake pipe.

Braking Force—The total force in pounds pressing the brake shoes against the wheels.

Braking Ratio—The ratio obtained by dividing the total braking force by the weight of the car or locomotive. It is usually expressed as a percentage value.

Brake Shoe—A replaceable friction element secured to the brake head for the purpose of producing retarding force. Two general types of brake shoe friction elements are used:

High Friction—Those friction elements which produce nominally 33% coefficient of friction at 60 mph by AAR Specification.

Low Friction—Those friction elements which produce nominally 15% coefficient of friction at 60 mph by AAR Specification.

Brake Shoe Key—A key by which a brake shoe is fastened to a brake head.

Brake Shoe Pressure—The force in pounds, rather than pressure, exerted by the brake shoe on the wheel when the brakes are applied. It is calculated by dividing the product of total piston force and leverage ratio by the number of brake shoes on the car or locomotive. This may or may not be adjusted for rigging friction and piston return spring force.

Brake System—Includes all brake apparatus working harmoniously on railway vehicles, such as the air brake, electro pneumatic brake, hand brake, and foundation brake gear.

Brake Valve, Automatic—See Automatic Brake Valve.

Brake Valve, Independent—A device, manually operated, to control the application and release of the locomotive brakes. A feature whereby the locomotive brakes can be released and applied independently of the train brakes.

Bureau of Railroad Safety—An element of the Federal Railroad Administration which provides advice and assistance to the FRA on all aspects of railroad safety; makes investigations of railroad accidents when appropriate; and enforces regulations relative to the Safety Appliances Act, Hours of Service Act, Accident Reports Act, Medals of Honor Act; Power Brake Law, Transportation of Hazardous Materials by Rail, Locomotive Inspection Act, and the Signal Inspection Law. Prior to creation of the Department of Transportation these functions were administered under the Interstate Commerce Commission and erroneously references continue to be made to "ICC inspection" and "ICC defect". Technically these should be "FRA inspection", "FRA defect", etc.

Caboose Valve—A device located on the caboose for applying air brakes on the train.

Canadian Transport Commission (CTC)—A federally appointed body formed to coordinate the operations of all carriers—air, land, pipeline—and to regulate their activities, licensing and tariffs. (See also Railway Transport Committee.)

Capacity of Car—The nominal load in pounds, gallons or cubic feet which the car is designed to carry.

Circuit Breaker—A device for opening, i.e. "breaking", an electric circuit automatically when the current exceeds a predetermined level.

Clasp Brake—A brake arrangement having two brake shoes per wheel.

Cock—A manually operated device used in pipes or valves to permit or prevent the flow of air.

Coefficient of Friction—The ratio between the braking force and the retarding force.

Compressor—(Commonly called "air pump")—A machine which provides compressed air for use in the air brake system and auxiliaries.

Contactor—A device similar to a relay, operated by a small electric current which opens or closes switches that are capable of handling large amounts of current.

Control Valve—A device on locomotive or cars which charges the reservoirs and moves to apply and release the brake cylinder pressure in response to the reduction or increase of brake pipe pressure.

Coupler, Air and Electric—A device which automatically provides pneumatic and electrical connections between cars, and/or locomotive units.

Coupler, Mechanical—An appliance for mechanically connecting cars and/or locomotives together. It is required that these couple automatically by impact and that they be able to be uncoupled without personnel going between the cars or locomotive units to uncouple them. The coupler complete comprises a draw head and a knuckle.

Cutout Valve—A name given to a variety of cocks or devices used for the purpose (as indicated by the name) of cutting in or out certain functions.

Cycle Braking—A method of applying and releasing brakes on a train over heavy descending grades with the use of retaining valves.

Department of Transportation—An executive department of the U. S. Federal Government, headed by a Secretary and formed to bring together many of the transportation activities of the Federal Government at a Cabinet level. Among the agencies comprising the Department are the Federal Railroad Administration, the Urban Mass Transportation Administration and the National Transportation Safety Board.

Direct Release—It is the normal release functioning of freight car brake equipments. When the control valve is moved to release position by brake pipe pressure increase, all of the brake cylinder pressure is directed to exhaust through the retainer. Passenger and locomotive brake equipments of 26-L and 24-RL types can be set to provide only direct release.

Distributing Valve—A device similar to a control valve that acts as an operating valve to charge, apply, and release the brakes. It may be controlled by the automatic or independent brake valves.

Double Check Valve—One having two seats so arranged that air flowing past either seat cannot flow out past the other seat but will flow through a third common delivery connection.

Double Head—Two locomotives coupled together and located on the head end of a train, with the power and the independent locomotive brake controlled separately by the engineman of each locomotive.

Double-Heading Cock—See "brake pipe cutout cock" or "cut-off valve".

Draft Gear—A shock cushioning unit, installed to transmit compression (buff) and tension (draft) forces between the coupler and the car or locomotive structure. The draft gear is housed within the coupler yoke and at the inboard end, bears against follower plates which press against draft lugs riveted or welded to the structure.

Drawbar Pull—The force exerted on the coupler between the locomotive and the car which is equal to the locomotive tractive effort less the rolling resistance of the locomotive.

Dummy Coupling—A device designed to couple to unused air hose to protect against damage to the hose and coupling, as well as preventing entrance of foreign matter into the hose.

Duplex Release Valve (Bleeder)—A two-valve mechanism for the draining of auxiliary reservoir and emergency reservoir air by means of a common rod. The handle pulled slightly opens the valve to drain auxiliary reservoir; when pulled the full distance, both valves open to drain both reservoirs.

Dynamic Brake—Dynamic braking is an electrical means used to convert some of the energy of a moving locomotive into an effective retarding force.

Electric Portion of Coupler—A device to connect various electric circuits.

Empty weights—(See Light weight).

Emergency Valve—A device for the purpose of initiating an emergency application.

Engine—An internal combustion engine of a locomotive used to drive the main generator or the mechanical hydraulic power train.

Engineman's Warning Lights and Alarm Bell—Numerous warning lights and an alarm bell are provided to inform the engineman of the status of the locomotive consist. Typically found are the following:

PCS will light in the event of an emergency or safety control air brake application.

Brake Warning will light when excessive dynamic brake current is developed on any unit in the consist.

Wheel Slip will light when any pair or pairs of wheel in the consist are slipping or sliding in power or dynamic brake.

No Power will light, on the unit affected, due to an abnormal engine shutdown or loss of control power. The alarm bell on all units will ring.

Low Oil will light, on the unit affected when the engine is shut down due to a loss of oil pressure or low water. The alarm bell on all units will ring.

Ground Relay will light, on the unit affected, when the ground relay has tripped. The alarm bell on all units will ring.

Hot Engine will light, on the unit affected, to indicate the engine cooling water temperature is excessive. The alarm bell on all units will ring.

Equalizing Reservoir—The small reservoir connected to an equalizing piston chamber to add volume to the piston chamber for use in making service applications.

Equalizing Reservoir Pressure—The pressure expressed in pounds per square inch of air in the equalizing reservoir on the locomotive.

Emergency Application—A reduction of brake pipe pressure at a rate faster than for service application and sufficient to cause the control valve to move to emergency position and produce a brake cylinder pressure higher than in service.

Fast and Slow Start—Some locomotives may be equipped with "fast start" to enable them to more satisfactorily perform switching operations. The controls are automatically altered so as to provide a more rapid buildup of load in response to throttle changes. Conversely, some switcher locomotives are equipped with "slow start", or road operation controls, to provide a slower buildup of load which is more conducive to the operation of freight trains across the road.

Federal Railroad Administration—A U. S. Federal agency attached to the Department of Transportation and comprising The Alaska Railroad, High Speed Ground Transportation and the Bureau of Railroad Safety. The FRA serves as the principal organization for assistance to the Secretary of Transportation on all matters relating to rail transport and safety.

Feed Valve—A valve which reduces main reservoir pressure to a determined amount for delivery to the equalizing reservoir and brake pipe.

First Service—A feature normally found in No. 8 and No. 24 equipment automatic train brake applications in which a light initial brake pipe reduction at a service rate is made, followed by a controlled continuous slower reduction.

Flat Maintaining—An operating feature of the No. 24 and No. 8 type locomotive brake equipments which in first service position maintains a controlled service rate of brake pipe reduction against brake pipe leakage.

Full Service Reduction—A reduction of brake pipe pressure at a service rate sufficient in amount to cause the maximum service brake cylinder pressure to develop.

Fuse—A strip of fusible metal alloy placed in series in an electrical circuit, designed to melt and open the circuit when the current exceeds a predetermined level.

Generator—A machine for converting rotational mechanical power into electrical power.

Graduated Release—A feature designed into locomotive and passenger brake equipment whereby brake cylinder pressure may be reduced in steps proportional to increments of brake pipe pressure build-up. Feature may be nullified to direct release when not desired.

Grade (or Track Gradient)—A measure of the inclination of railway track. In North American practice grade is usually stated in per cent meaning the number of feet of rise or fall in 100 feet of horizontal distance along the track: i.e., 1.67% or 1%. Elsewhere track grade is usually expressed in terms of the distance along the track for 1 unit of rise or fall: i.e. the above grades would be expressed as 1 in 60 and 1 in 100.

Grid—An electrical resistor capable of dissipating quantities of electrical power.

Gross Rail Load—The sum of the axle capacities.

Gross Weight—The total weight of a car including the lading.

Hand Brake—An apparatus installed on cars and locomotive units by means of which brakes on that car or unit can be applied by hand.

Hose Coupling—A device on the free end of an air hose so that it can be coupled to another hose having a similar hose coupling, colloquially termed "gladhand".

Hump Control—Allows the engineman an infinite control between

no load and full load in order to obtain close control of train speed. Hump control transfers the locomotive load control from the throttle handle to a rheostat on the engineman's control stand. On some locomotive models the engine speed is automatically increased to provide adequate cooling air for the traction motors. On other locomotive models, it will be necessary for the engineman to increase the throttle position manually as the load will be limited in each throttle position.

IDAC—The name is made up of the first letters of the following words describing a wheel slip control system on EMD locomotives: "Instantaneous Detection and Correction", (See Technical Appendix for Description.)

Isolation-Run Switch—The isolation-run switch on diesel-electric locomotives has two positions. In the Run position the unit is placed "on the line" and will respond to control and will develop power in operation. In the Isolation (or start-stop) position, the unit is isolated from the consist and will not develop power nor respond to control but will remain in an engine idle condition. The Isolation position is also used for setting up controls to normally stop or silence the alarm bell.

Jumper—A flexible cable, containing one or more conductors insulated from one another, covered with suitable material to resist abrasion used to connect the electrical control circuits between cars or locomotive units.

Kinetic Friction—Friction of motion; as between a brake shoe and rolling wheel; also, between the wheel and the rail during sliding. Generally, Kinetic Friction is less than static friction.

Knuckle—The pivoted end joint of a Mechanical coupler by means of which coupling is effected between cars and/or locomotive units when the knuckle is locked.

Leverage—The system of levers used to transmit the delivered braking force from the brake cylinder or hand brake to the brake shoes.

Leverage Ratio—The mechanical advantage obtained through a system of levers; generally in air brake practice the ratio of the braking force pressing shoes against the wheels to the cylinder force.

Limiting Valve—A device to restrict the operation of another device or function as to time, pressure, or both.

Live Levers—Levers not having fixed or nonmovable connections at any point.

Light Weight—A term used to describe the car weight without any lading.

Load Indicating Meter—The loadmeter reads the measure of amperage flowing through each of the locomotive units traction motors. Since amperage through the motor, for a given step of field shunt, is proportional to torque or force developed at the motor shaft, the meter can be used as a "Pull Meter" to indicate the tractive effort of the locomotive.

Load Limit—The combined light weight of a car and the load weight which gives the maximum AAR axle loading.

Locomotive—A unit propelled by any form of energy or a combination of such units operating from a single control station.

Main Reservoir—A reservoir on the locomotive for storing and cooling compressed air.

Motor—A machine for converting electrical power into mechanical power.

National Transportation Safety Board—A U. S. Federal agency attached to the Department of Transportation and consisting of five members appointed by the President with the consent of the Senate. Its functions, powers and duties relate primarily to the determination of probable causes of transportation accidents; appellate review of the suspension, modification, revocation or denial of certificates and licenses; and the investigation of aircraft accidents.

Ohm—The unit of electrical resistance which is a measure of the restriction to current flow through a conductor on which a given voltage is acting. The electrical term "ohm" or "resistance" is analogous to the inside diameter of a water pipe which will restrict the amount of water flow for a given water pressure.

Overcharge—Brake equipment charged to a higher pressure than that for which the feed valve is adjusted.

Over-Reduction—A service brake pipe reduction to a pressure lower than that at which the reservoir and the cylinder equalize.

Overspeed—A speed greater than the maximum authorized speed for the locomotive, cars, track or components often associated with an overspeed penalty brake application.

"P" Wire—A electronic system controlling either braking or power depending on its amperage.

Power Brake—A combination of parts operated by compressed air or force other than hand, controlled manually, pneumatically, or electrically, by means of which the motion of a train, car or locomotive is retarded or stopped.

Pressure Maintaining—An automatic brake valve feature included in the 26-C type and available for 24-RL type which will maintain brake pipe pressure the same as equalizing reservoir pressure against the effects of brake pipe leakage.

Pressure Retaining Valve—See Retaining Valve.

Propagation—The serial action of transmitting a brake application from car to car through a train, such as in quick action, emergency or quick service.

Quick Action—The feature whereby the emergency brake pipe reduction is passed rapidly from car to car throughout the train.

Quick Release Portion—A portion of the 26-F Control Valve which

is operated by the actuating function of the independent brake valve to release the locomotive brakes when an automatic train brake application is in effect.

Quick Release Valve—A device located in the brake cylinder line to provide a fast local release.

Quick Service—A feature which provides a controlled service rate of brake pipe reduction through a local reduction of brake pipe pressure at each car.

Quick Service Limiting Valve—A portion of a control valve that nullifies further quick service activity when the brake cylinder or displacement reservoir pressure reaches approximately 10 psi.

Quick Service Valve—A device auxiliary to the control valve to assist in reducing brake pipe pressure, providing continuous quick service regardless of brake cylinder or displacement reservoir pressure. Each brake pipe reduction will cause the quick service valve to respond.

Railway Association of Canada (RAC)—An organization representing all railroads operating in Canada, for the purposes of collective action.

Railway Transport Committee (RTC)—An agency of the Canadian Transport Commission having jurisdiction over railway matters and the administration of railroad safety under the Railway Act.

Rate of Retardation—Rate of speed reduction over a period of time. for example: If the speed is reduced from 60 mph to 57 mph in 1 second, the rate of retardation is an average of 3 mph per second during that second.

Reducing Valve—A valve which reduces a high pressure to a lower pressure maintaining a predetermined setting.

Reduction, Brake Pipe—A decrease of the brake pipe pressure at a rate and in an amount sufficient to cause a brake application.

Reduction Relay Valve—A combination of an emergency vent valve and a continuous quick service valve mounted on a common pipe bracket, and designed for application to long freight cars to offset the effect of the increased volume and length of brake pipe per car by promoting quick service activity as well as ensuring the transmission of an emergency application through a train of long cars.

Relay—A device operated by an electric current which automatically causes any number of switches to open or close to change the electrical conditions in other circuits.

Relay Valve—A device that receives controlling pressure from a source and operates to deliver and maintain a corresponding pressure. It is frequently located close to a supply reservoir and one or more brake cylinders to hasten the time of application and release. Through differential diaphragms of different sizes a lower or higher pressure may be delivered.

Relay Air Valve—A registered trademark name of a device that op-

erates from a controlling device upon a small volume of air for delivering or exhausting a large volume of air. It differs from a relay valve in that it does not respond to increments of controlling pressure change.

Retaining Valve—A control device through which brake cylinder air is exhausted completely or a predetermined brake cylinder pressure is retained.

Retarding Force—The sum of external forces acting on a moving body tending to oppose continued motion. In train braking, the brake retarding force is the product of the actual brake shoe force and the instantaneous coefficient of friction at the braking contact surfaces.

Rotair Valve—A registered trademark name for a rotary type valve controlling the flow of air to and from various parts, devices, supply sources, etc.

Running Release—Release of an automatic service application while the train is in motion.

Safety Control—A device or devices which will cause an automatic brake application to be initiated when the engineman becomes incapacitated.

Safety Valve—A device which vents pressure in excess of the setting.

Sander Valve or Sander Switch—A manually operated device for initiating sanding.

Service Application—A reduction of brake pipe pressure at a rate and amount sufficient to cause the control valve to move to service position.

Service Brake—A brake application at a service rate and limited to a brake cylinder pressure less than in emergency.

Service Rate—The rate, slower than emergency, which the brake pipe pressure reduces to cause a control valve to assume service position.

Single Shoe Brake—Where one brake shoe is used on a wheel contrasted with clasp type brake where two brake shoes are used, one on each side of the wheel.

Slack—There are two kinds of slack: One is termed "Free Slack" and is the accumulation of clearances and wear in the associated parts of the couplers. The other type of slack is often called "Spring Slack" and results from the compression of the draft gears.

Split Reduction—Where, instead of one heavy initial continuous reduction of the brake pipe, the initial reduction is made only to a partial degree, with further reductions to the desired total amount.

Switch—A device used to open, close or divert an electric current, which is analogous to, e.g., an air valve. A switch may be manually operated or automatically operated, by such things as pressure, temperature, or speed.

Tare Weight—The weight of the empty car.

Tons per Operative Brake—The gross trailing tonnage of the train

divided by the total number of cars having operative brakes, for example: total train weight 6000 tons, total cars 100 all brakes operating: divide 6000 by 100 and there is 60 tons per operative brake.

Tractive Effort—The force developed at all the locomotive driving wheels parallel to rail to move the locomotive and cars. This force is expressed in pounds and is directly proportional to the locomotive horsepower and inversely proportional to the locomotive speed.

Vent Valve—The name applied to a valve or valvular portion of a car or locomotive brake system which responds to an emergency rate of reduction of the brake pipe and in turn vents the brake pipe locally at each vehicle, thereby propagating serially the emergency application throughout the train.

Volt (Voltage)—the unit of electric force or potential. One volt potential will cause one ampere to flow through a conductor of one ohm. The electric term of voltage is analogous to, e.g., water pressure, in which pounds per square inch of pressure has the potential to cause water to flow whenever released.

Watt—A unit of electric power equal to a current flow of one ampere under one volt of pressure; 746 watts equal one horsepower; 1000 watts equal one kilowatt.

Wheel Slipping—The wheel rotating on its axis with motion existing between the wheel and rail at the area of contact.

Wheel Sliding—The wheel not rotating on its axis and relative motion existing between the wheel and rail at the area of contact.

Yard Plant—A system of piping and fittings installed between the tracks in such a manner that an air supply can be furnished at convenient locations for charging and making tests on cars previous to a locomotive being available.

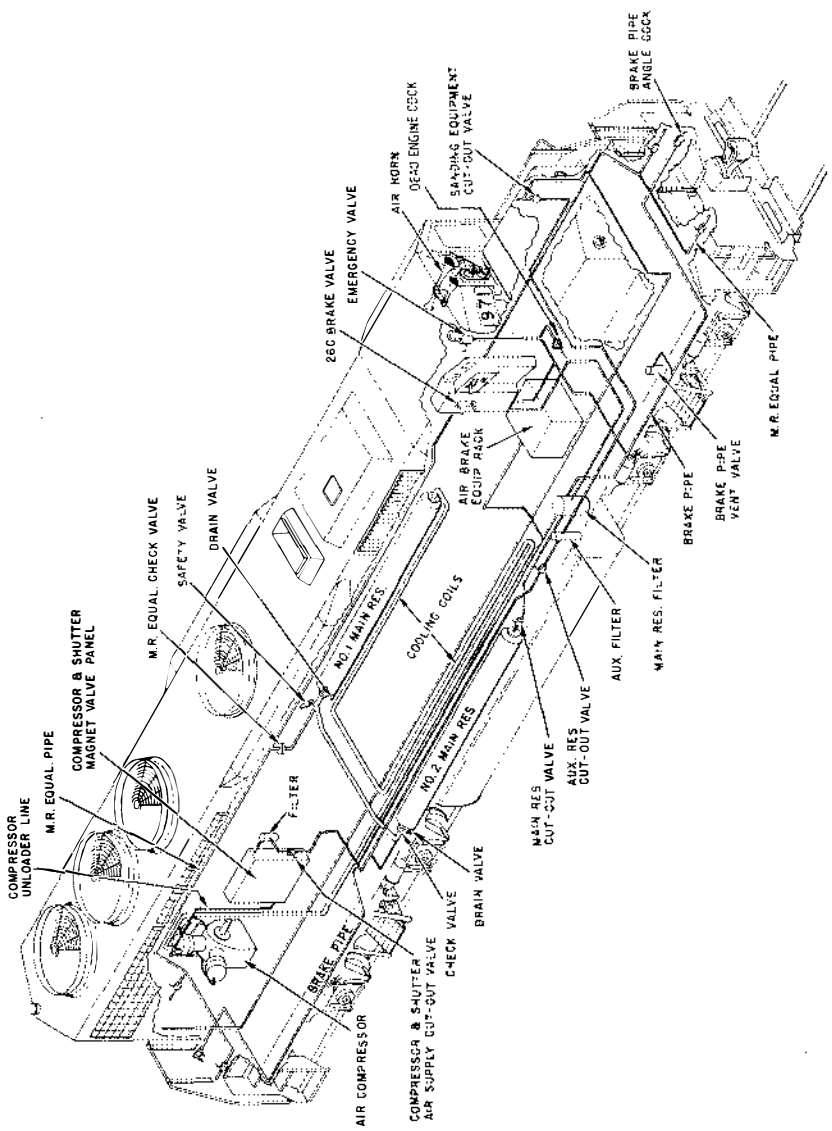


FIG. 1

CHAPTER II — THE TRAIN BRAKE SYSTEM

General

The train brake system includes:

1) the air brake equipment on the locomotive units and on the cars;
2) the dynamic brake equipment on the locomotive units.

The air brake and the dynamic brake may be used by the engineman either separately or in conjunction with the other to stop or to control the speed of the train.

Locomotive air brake equipment

A typical arrangement of the major components of the locomotive air brake equipment is shown in Fig. 1.

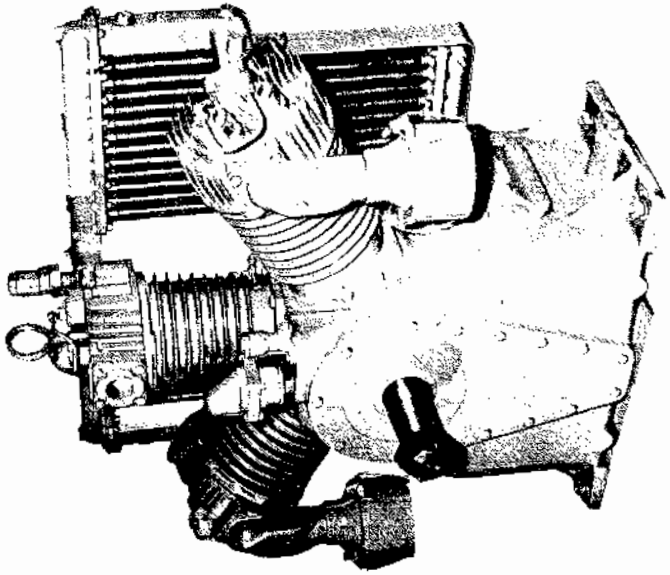
A supply of compressed air is provided by the air compressor or compressors. The air compressor is usually driven directly from the diesel engine but it can be driven by an electric motor or by a separate auxiliary diesel engine.

Locomotive air compressors usually are of the reciprocating type as illustrated in Fig. 2, embodying a crankshaft and connecting rods which move pistons up and down in the cylinders. On the downstroke atmospheric air is sucked through a filter, past an inlet valve, and into the cylinder. On the upstroke the inlet valve closes and the air is compressed and expelled through the discharge valve into the next stage or into the discharge pipe leading to the reservoir.

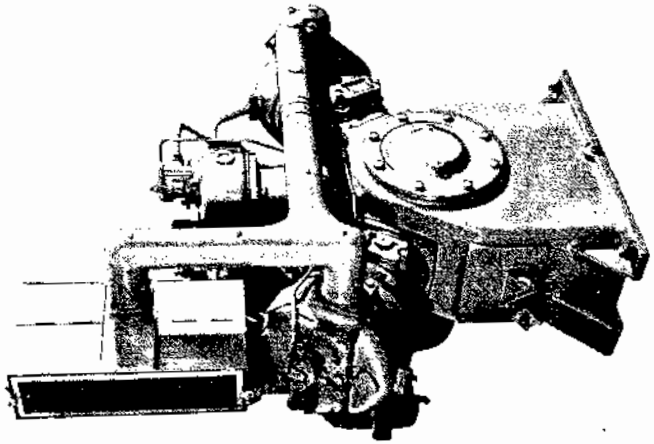
Reciprocating compressors for locomotive use may employ 2, 3 or 6 cylinders; in almost all cases they use 2 stages of compression. A 3-cylinder machine, for example, has 2 low-pressure cylinders and one high-pressure cylinder with an intercooler between the two stages of compression to cool the air from the two low-pressure cylinders before it passes to the high-pressure cylinder.

A governor is provided to load and unload the compressor so as to maintain air pressure within the desired limits, usually 130 to 140 psi. One type of compressor governor, the S-16, is shown in Fig. 3. It has two pressure settings, HP or cut out (usually 140 psi) and LP or cut in (usually 130 psi). The S-16 governor includes an electric switch called the compressor cutout switch, activated by the pneumatic portion, which through a synchronizing wire circuit and magnet valves (such as the type FA-4 shown in Fig. 4) will cause all of the compressors of a multiple unit consist to start pumping at the same time. Units not equipped for synchronous compressor operation can have an NS-16 governor which is similar to the S-16 but has no cutout switch.

Figs. 5 and 6 illustrate an alternative type of synchronous compressor control incorporating a dual-pressure switch for a governor. MV-CC is the magnet valve which controls the compressor unloader valves to



AIR COOLED



WATER COOLED

FIG. 2 AIR COMPRESSORS

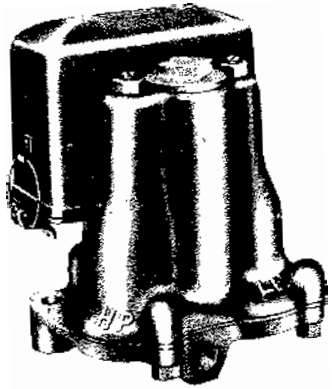


FIG. 3 AIR COMPRESSOR GOVERNOR

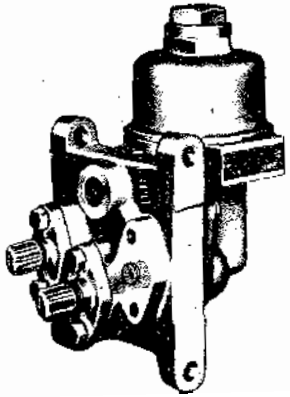
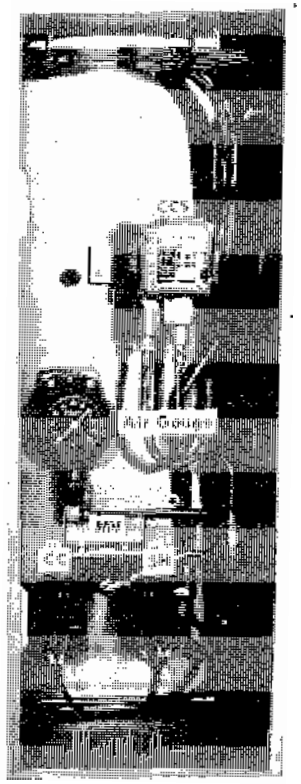


FIG. 4 UNLOADER MAGNET VALVE



prevent building up excess pressure which would have to be vented at the 150-psi main reservoir safety valve. Local maximum pressure control through circuit No. 2 will unload the compressor of any unit on which the pressure reaches nominally 145 psi.

FIG. 5 AIR COMPRESSOR CONTROL CABINET

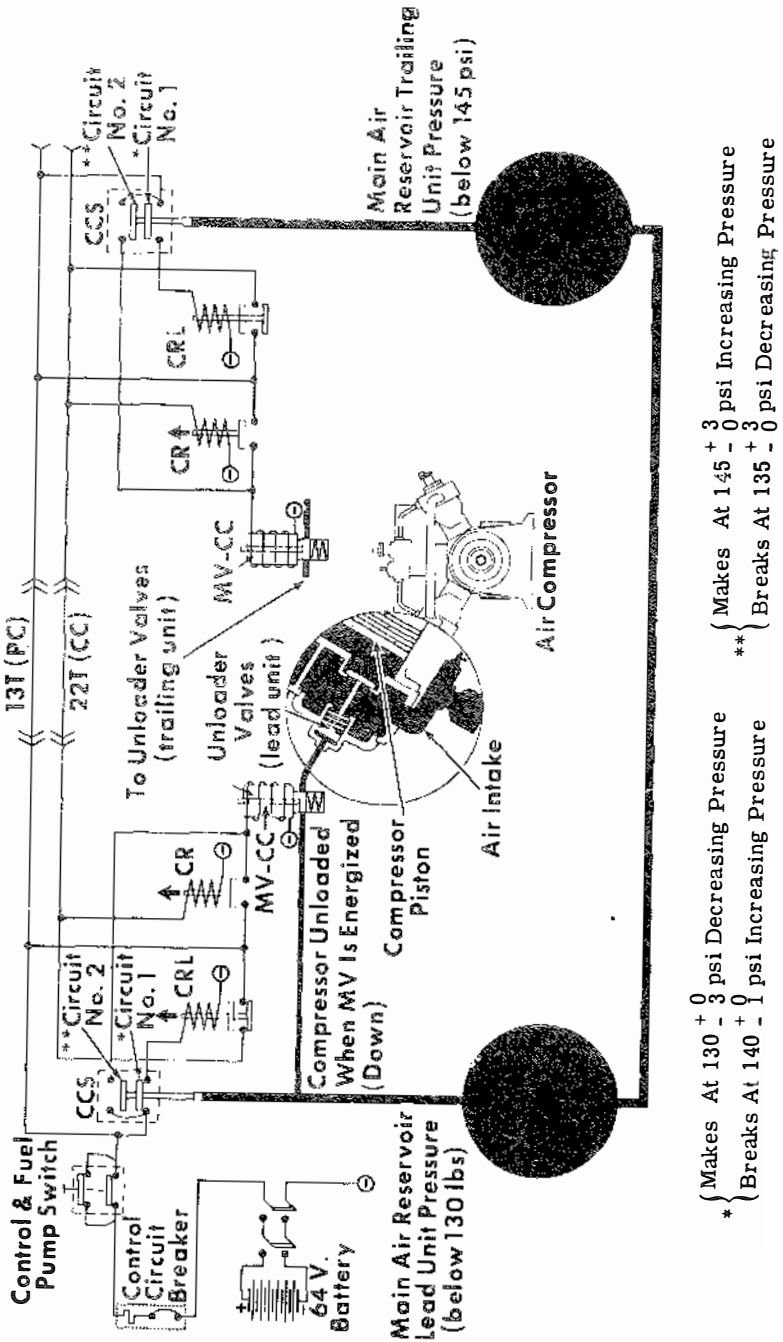


FIG. 6 ELECTRO-PNEUMATIC COMPRESSOR CONTROL

FIG. 7 AUTOMATIC DRAIN VALVE WITH SUMP

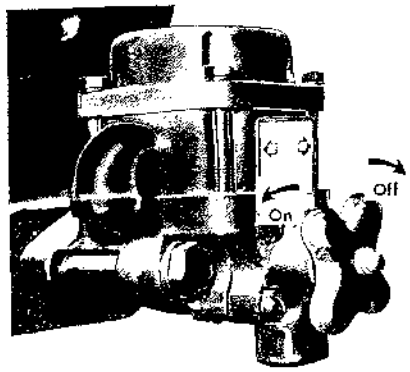


FIG. 8 COMBINED AUTOMATIC AND MANUAL DRAIN VALVE

An unloader is provided for each inlet valve on a compressor. When loaded or cut in, the unloader allows the inlet valve to operate normally, i.e. to open at the beginning of the suction stroke and to close at the beginning of the compresson stroke. When unloaded or cut out, the unloader holds the inlet valve open to prevent compression of air in cylinder from taking place.

Since air becomes heated when compressed, cooling must be provided for the cylinder heads and the intercooler. Two methods are in common use:

1) Air-cooled machines have raised fins on the primary radiating surfaces (cylinder bodies and heads) to dissipate heat to the air surrounding the compressor. Some compressors employ a fan to increase the flow of air over the cylinders for this purpose. Intercoolers of air-cooled compressors use finned tubing to aid in heat dissipation.
2) Water-cooled machines have passages in the cylinders, heads and intercooler through which diesel engine coolant is circulated to carry away unwanted heat to the radiators.

The low-pressure stage of a two-stage reciprocating compressor draws in air at atmospheric compressor in the suction stroke, discharging it during the compression stroke, at a pressure of 40 to 50 psi, through the discharge valve into the intercooler where excess heat is removed. When the piston of the high-pressure cylinder is starting its suction stroke, air from the intercooler enters the high-pressure cylinder to begin the second stage of compression.

Air discharging at 140 psi from the high-pressure cylinder has heated up again. The heat imparted to the air in the second stage of compression is removed in radiating pipes or aftercoolers which are usually located outside the locomotive body where exposure to the atmosphere can provide the most effective cooling.

Compressed air is stored on the locomotive in large volume main reservoirs. These reservoirs, usually two in number, are generally located outside the locomotive body, and they also provide some aftercooling effect. Another function provided by the main reservoir is that of a large sump to collect moisture which precipitates as the compressed air cools.

When air is compressed to 140 psi, it is squeezed to about one-tenth of its original volume. This means that there is now 10 times as much moisture in each actual cubic foot of the compressed air as there was at atmospheric conditions. The ability of compressed air to hold moisture depends primarily on the volume and temperature, i.e. 1 cubic foot of air at given temperature and pressure can hold only a specific amount of moisture. Therefore, considerable moisture will drop out of the air in the aftercooling pipe. Most of it will precipitate in the aftercooling pipe between the compressor and the first main reservoir, because this is where the temperature drop due to cooling is the greatest. Usually about

85% of the moisture will collect in the first main reservoir. The second main reservoir will collect about 15%. This is why it is necessary to drain main reservoirs regularly or use automatic drain valves. See Fig. 7 and Fig. 8.

In order to have a volume of air stored specifically for use in the locomotive brake cylinders and brake system, the compressed air flows from the first to the second main reservoir through a check valve. From the second main reservoir, air flows to the automatic brake valve through a filter and moisture trap. At the point where the main reservoir air enters the locomotive brake equipment, it is at approximately 140 psi and is usually 100% saturated with moisture.

Control of air to the train brake system

At the automatic brake valve the pressure of the air delivered from the main reservoirs to the train brake system is reduced by a regulating valve to the brake pipe pressure carried for the particular train service. Brake pipe pressures in common use range between 70 and 110 psi, depending on the railroad and its type of service.

In undergoing this pressure reduction air expands, increasing its ability to carry moisture (or in effect reducing the humidity of the air) so that the relative humidity of the air in the brake pipe commonly ranges between 70 and 80% of saturation.

The 26-C automatic brake valve, shown in Fig. 9, supplies the brake pipe with air which is used for the following purposes:

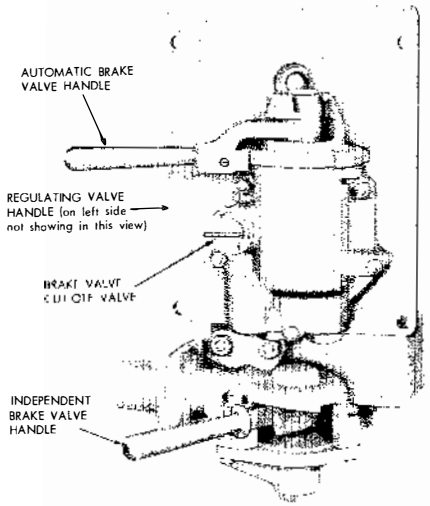


FIG. 9 26-C AUTOMATIC BRAKE VALVE

1. To charge the auxiliary, emergency and supply reservoirs of the car brake equipment and the auxiliary reservoirs of the locomotive equipment.
2. To vary the brake pipe pressure to cause the automatic train brakes to apply and release in service and emergency.

After the train is charged with the automatic brake valve handle in release position, movement to the right will cause a reduction in the equalizing reservoir pressure. This in turn will cause the brake pipe pressure to reduce a corresponding amount. Specific handle positions determine the specific pressure in the equalizing reservoir.

a. That is, leaving the brake valve handle in a position which reduced the equalizing reservoir pressure by, say 10 psi, will cause the brake pipe pressure to reduce 10 psi. Since the 26-C brake valve is of the "pressure maintaining type", the brake pipe pressure reduction of 10 psi will be held or maintained against the effect of the nominal brake pipe leakage.

b. Reducing the brake pipe pressure will cause the locomotive 26-F control valve (Fig. 11) and train brakes to apply.

c. The 26-C automatic brake valve handle positions are shown in Fig. 10 and are:

1. Release-Equalizing reservoir and brake pipe correspond to regulating valve setting, 70 to 110 psi, as required for the particular train service.

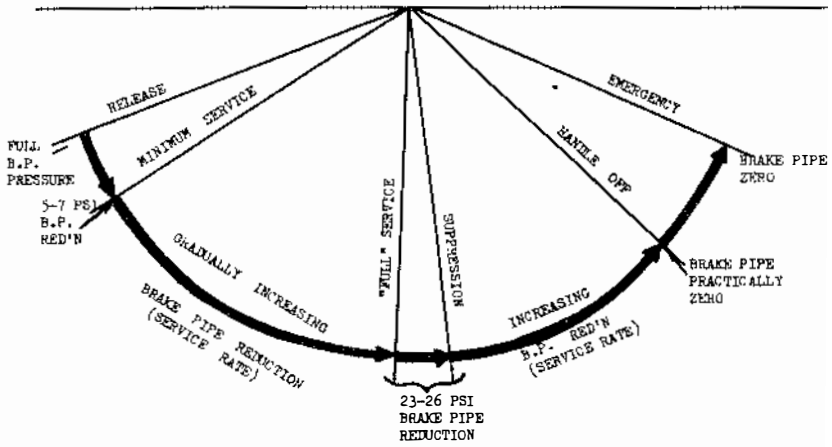


FIG. 10 26-C AUTOMATIC BRAKE VALVE HANDLE POSITIONS

2. Minimum Service Reduction: 5-7 psi reduction in equalization reservoir and brake pipe pressure. Pressure can be further reduced in steps by moving handle progressively to the right.
3. Full service - 23-26 psi reduction of equalizing reservoir and brake pipe.
4. Suppression - 23-26 psi brake pipe reduction plus air into port #26 or "Suppression Pipe" to permanently suppress safety control or train control. Additional movement to the right toward "Handle Off" will progressively reduce brake pipe at a service rate.
5. Handle off - Brake pipe is further reduced to approximately 10 psi. Equalizing reservoir will be reduced to approximately 0.
6. Emergency - Brake pipe is quickly vented through a large opening to atmosphere and equalizing reservoir vents to atmosphere at normal rate.

d. The setting of the regulating valve of the 26-C automatic brake valve controls the maximum pressure that can be put into the equalizing reservoir. Equalizing reservoir pressure acts on the relay valve portion of the 26-C brake valve and causes it to reproduce the same pressure in the brake pipe. Actually moving the automatic brake valve handle (the larger handle on Fig. 9) of the 26-C automatic brake valve, basically controls equalizing reservoir pressure, which in turn, controls brake pipe pressure through the relay valve portion.

e. The brake pipe reduction causes the 26-F control valve (Fig. 11) and the J type relay valve to put air pressure into the locomotive brake cylinders. The reduction in brake pipe pressure also causes the car brake equipments to respond similarly putting air pressure into the car brake cylinders.

f. Moving the handle of the 26-C automatic brake valve to the far right to "Emergency" will cause a very rapid reduction in brake pipe pressure. This will cause the 26-F control valve on the locomotive and all the car equipments to quickly respond to put maximum pressure into the brake cylinders.

g. The action of the brake valve cut off valve handle, having "in" and "out" on the escutcheon plate, cuts in or cuts out the 26-C brake valve from being able to control brake pipe pressure. However, an emergency application can always be made even though the brake valve cut off valve is in "out" position.

h. The smaller, lower brake valve handle, Fig. 9, operates the 26-C independent brake valve portion. This varies the control pressure to the J type relay valve, independently of the train brake action called for by the automatic brake valve handle. On many locomotives equipped with composition brake shoes the differential type J relay valve is

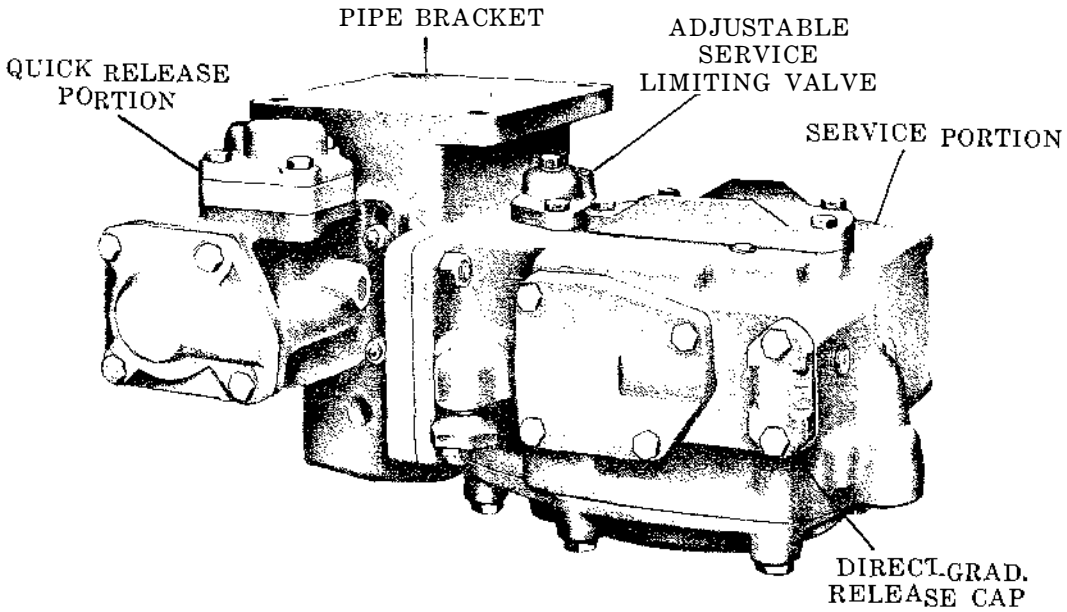


FIG. 11 26-F CONTROL VALVE

used. The differential type relay valve allows a higher brake cylinder pressure during independent braking than can be obtained with the automatic service brake operation. Depressing the independent brake valve handle will cause the quick release portion of the 26-F control valve (left hand side, Fig. 11) to release the locomotive brake cylinder pressure even though there is an automatic train brake service or emergency application in effect.

i. A standard J-1 (Figs. 13, 14, 15) Relay Valve will supply a large volume of air at a pressure equal to the control pipe pressure. Many times it is desired to have a pressure output which is less than, or greater than, the control pipe pressure, so a differential relay valve is used. There are basically two types of differential relay valves; a relay that can step up and relay that can step down the control pipe pressure. In addition, the step-up type relay can be piped to step down the control pipe pressure if such control is required.

The designation of the "J" Type Relay Valve refers to the relationship between the output pressure and the control pipe pressure. For example, a J-1, Fig. 13, Relay will put out 100% of the control pipe pressure and a J-16, Fig. 18, 19, can put out either 100% or 60% depending on how it was piped. A J-1.6-16, commonly called a step-up relay Fig. 16, 17, can yield 60%, 100% or 160% of the control pipe pressure. A J-46-B, which is commonly called a step-down relay, Fig. 20, 21, 22, can yield either 40% or 60%. Other combinations also are available.

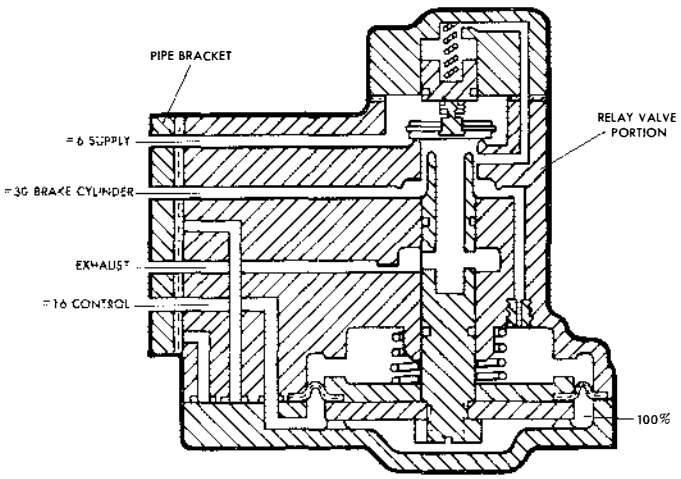


FIG. 13 J-1 RELAY VALVE

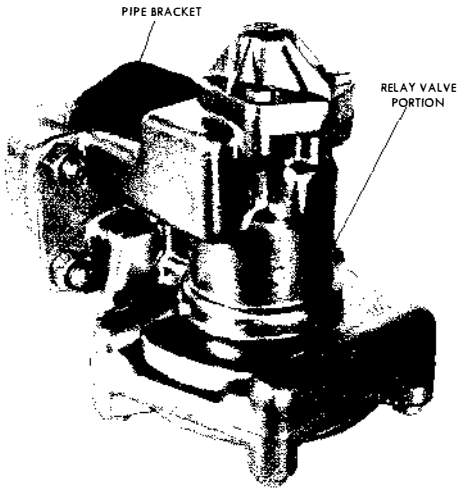


FIG. 14 J-1 RELAY VALVE

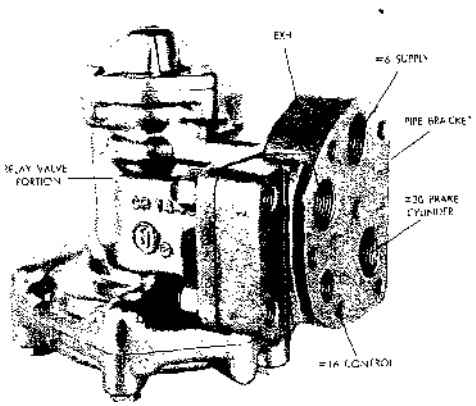


FIG. 15 J-1 RELAY VALVE

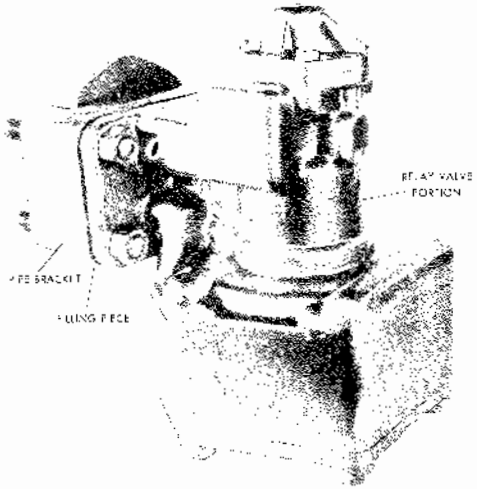


FIG. 16 J-1.6-16 STEP-UP

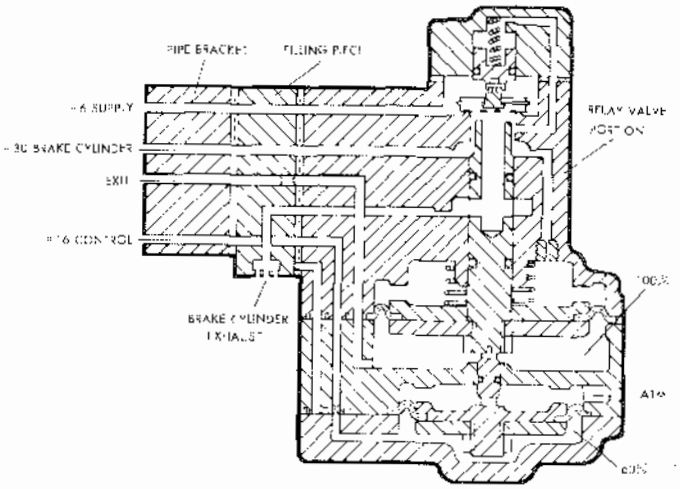


FIG. 17 J-1.6-16 B STEP-UP TYPE

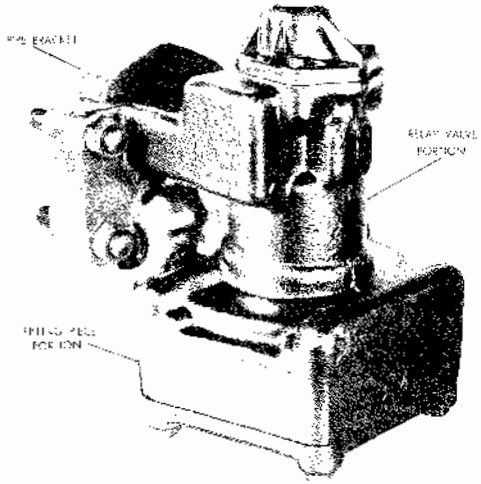


FIG. 19

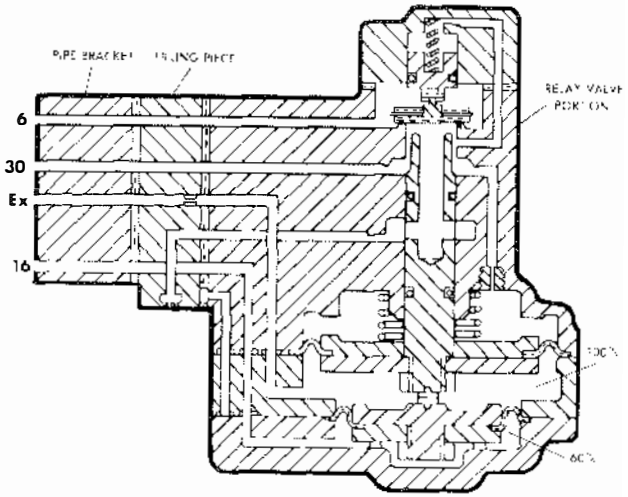


FIG. 18 J-16 RELAY VALVE

The J-1 Relay Valve is used when no modification in pressure is desired. The step-up relays, such as the J-1.6-16, are usually used on locomotives which have rigging arranged to use high friction brake shoes. The step-down relay, such as the J-46-B, is used on locomotives which have rigging arranged for low friction shoes, but are braked with high friction shoes. The 40% output pressure, or lower output pressure, would be used for automatic braking and the 60% or higher output pressure would be used for independent braking.

When using a step-down relay, Fig. 20, 21, 22, a problem could arise when a light brake application is made. For example, if 10 psi is supplied to the control pipe, the relay's output pressure to the brake cylinder would be just 4 psi and this might not be enough pressure to move the shoes against the wheel. So, an inshot valve has been added which is mounted on the relay bracket, allowing the 100% diaphragm to function until 7 psi is reached in the brake-cylinder pipe. This is indicated by the suffix letter "B" in the designation.

One of the ports in the pipe bracket of the "J" type differential relay has a 1/16" choke. This is to provide some degree of braking if a diaphragm is ruptured. Each relay is doweled to fit only its bracket. The dowels should never be removed to permit a spare relay valve to be applied on existing bracket.

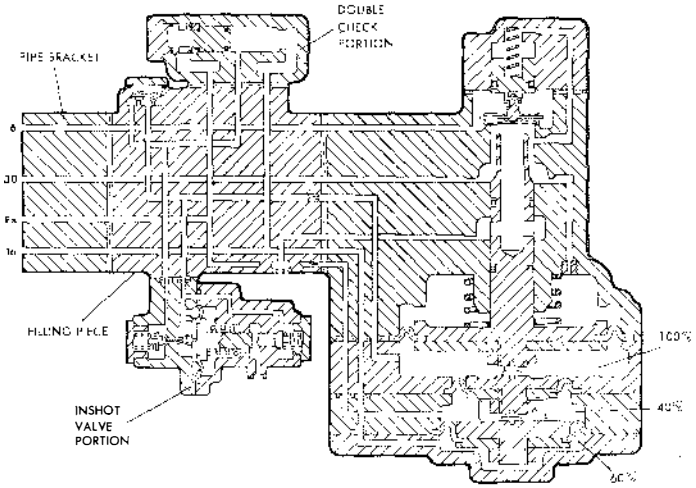


FIG. 20 STEP DOWN

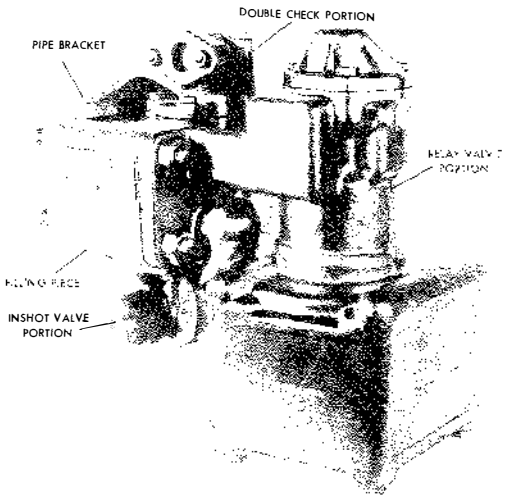


FIG. 21

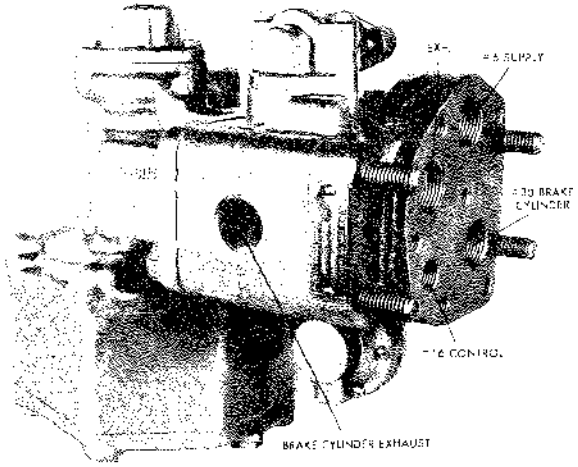


FIG. 22 STEP DOWN J TYPE RELAY VALVES

j. In order to properly position the air brake controls for operation of the independent brake, the MU-2-A valve (Fig. 23) or a double ported cut out cock, must be properly positioned; for example:

1. As shown, the MU-2-A valve is in "LEAD" position, for the controlling locomotive unit of a multiple consist or for single unit operation. The MU-2-A valve is also carried in this position if the locomotive unit is being hauled "DEAD" in the train.
2. If the particular locomotive unit is trailing a lead unit having No. 6 or No. 14 type brake equipment (single pipe MU), place the MU-2-A valve in "TRAIL 6 or 26."
3. If the particular locomotive is trailing a lead unit equipped with 24-RL, 8-EL (2 pipe MU), place the MU-2-A valve in "TRAIL 24."
4. With a double ported cock used in place of the MU-2 valve, it must be placed in "LEAD" (open) or "TRAIL" (closed) as the case may be.

FIG. 24 TYPE D DIAPHRAGM FOOT VALVE

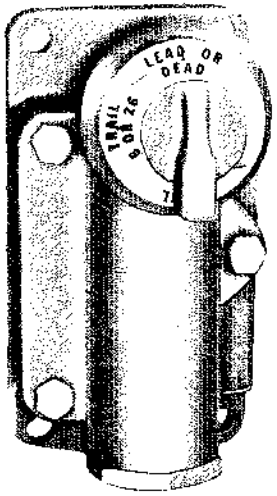


FIG. 23
MU-2-A VALVE

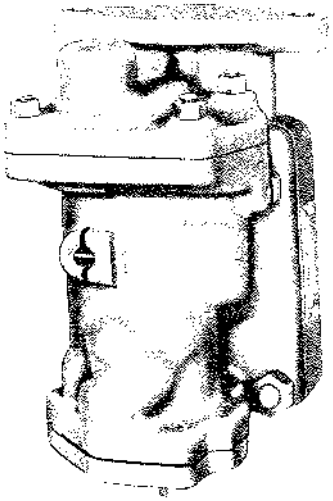


FIG. 25
P-2-A BRAKE
APPLICATION VALVE

SAFETY CONTROL

a. Safety control provides an automatic train brake application if the engineman does not keep the foot pedal depressed (Fig. 24). If the foot pedal goes up the P-2-A brake application valve (Fig. 25) operates to cause a reduction in equalizing reservoir pressure and, consequently, a brake pipe reduction which results in applying locomotive and train brakes, even though the automatic brake valve handle may be in release position. This is often called a penalty brake application.

b. Alertness control is available by using the A-1 cycling valve in conjunction with safety control foot valve, and P-2-A brake application valve. Other forms of alertness control ultimately cause the P-2-A brake application valve to operate if engineman does not respond properly.

c. When an automatic or independent brake application is in effect with the brake cylinder pressure approximately 25 psi or more, the operation of the P-2-A brake application valve is suppressed. With 25 psi or more, brake cylinder pressure the foot pedal can be released without causing a penalty brake application.

d. When the 26-C automatic brake valve handle is placed in "suppression" position, air pressure is supplied from the automatic brake valve through a double check valve to the P-2-A brake application valve. This holds action of the P-2-A brake application valve suppressed and prevents a penalty brake application.

e. Reset of Penalty Brake Application
If a penalty brake application occurs, the P-2-A brake application valve will remain in applied position until the 26-C automatic brake valve handle is placed in suppression position and the foot pedal held depressed for a sufficient time for the P-2-A brake application valve to reset itself to release position.

AUTOMATIC SPLIT REDUCTION

Some railroads install the A-1 or A-2 reduction selector brake application valve (Fig. 26) which, acting in conjunction with the P-2-A brake application valve, causes a split service reduction to be made automatically in case of a penalty application from a safety control, overspeed control or automatic train stop equipment.

AUTOMATIC TRAIN STOP OR AUTOMATIC TRAIN CONTROL

a. These are commonly termed "ATS" and "ATC." This type of control has a direct tie-in with the wayside signal system. If a restrictive block is entered and no action is taken by the engineman, either ATS or ATC will cause the P-2-A brake application valve to operate and make a penalty application of the train brakes.

b. With automatic train control (ATC), the C-1 suppression valve may be used (Fig. 27). The C-1 suppression valve allows an ATC penalty brake application to be temporarily suppressed or forestalled by making a series of small brake pipe reductions with the 26-C automatic brake valve.

Temporary suppression is available to take care of the situation where the restricted signal indication may clear after a short period of time and to give the engineman adequate time to slow a train down under manual control to the speed allowed for by the restrictive signal condition.

c. When the 26-C automatic brake valve handle is in suppression position, the ATC penalty brake application will be permanently suppressed. Brake pipe reduction in suppression position will be 23-26 psi or a "full service" reduction.

d. Automatic train stop is usually a somewhat simpler equipment, involving actuation of the P-2-A brake application valve by means of a magnet valve. The A-1 or A-2 reduction selector valves may be used in conjunction with it if automatic split reduction or automatic split reduction with temporary suppression are included.

OVERSPEED CONTROL

Overspeed control will cause a penalty brake application to occur through the P-2-A brake application valve, if the locomotive speed increases above the safe speed for the particular traction motors and gearing. In many cases, overspeed control cannot be suppressed by making a service brake pipe reduction. Overspeed control usually includes some means of audible and visual warning before going into action.

BREAK-IN-TWO PROTECTION

a. Most locomotives arranged for multiple unit operation are equipped with an A-1 Charging Cut Off Pilot Valve (Fig. 28), or its equivalent. When an emergency application occurs from any source, the A-1 Charging Cut Off Pilot valve responds by going to application position where it:

1. Delivers air pressure to the brake valve (53 port) which immediately cuts off air flow to the brake pipe.

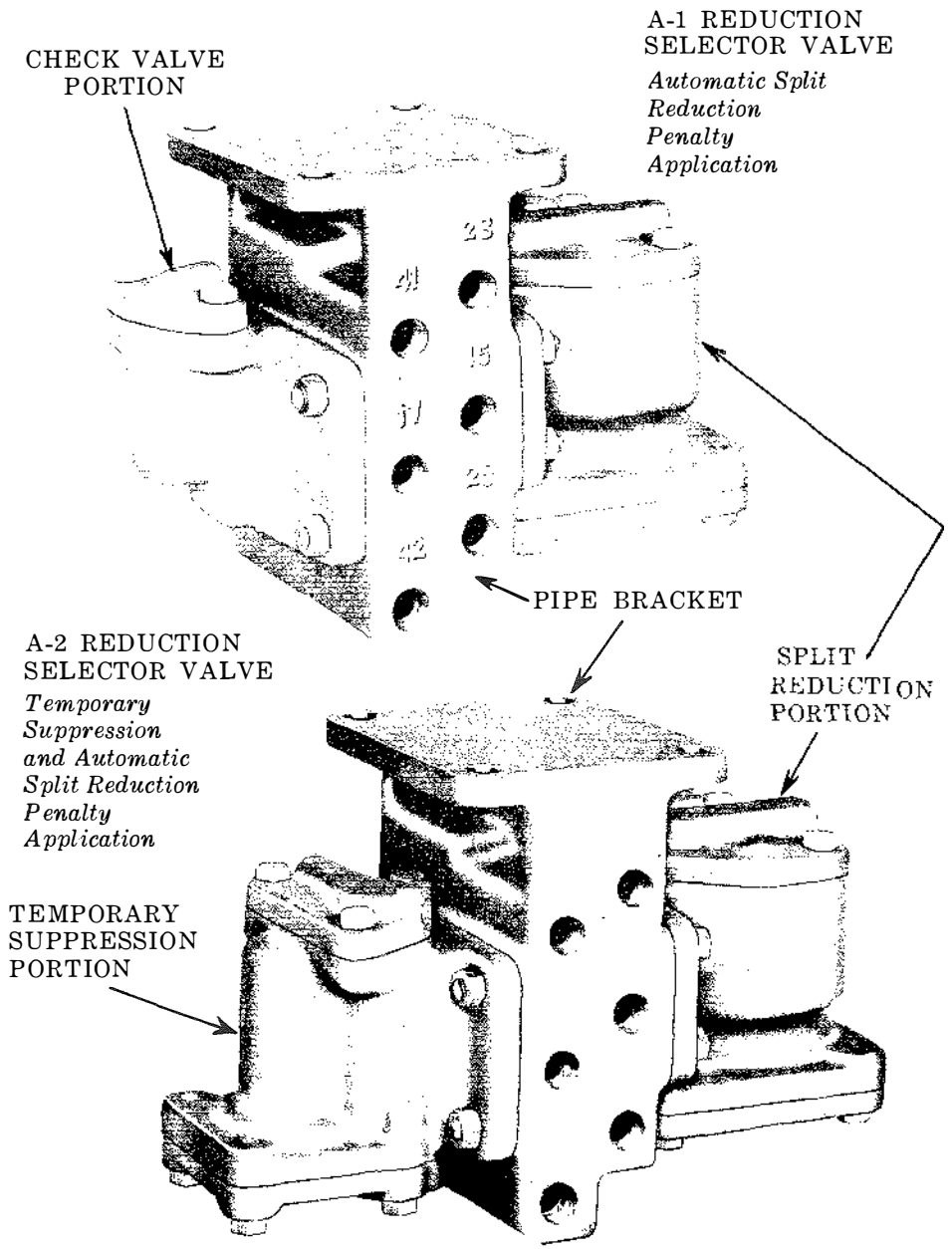


FIG. 26 A-1 & A-2 SELECTOR VALVES

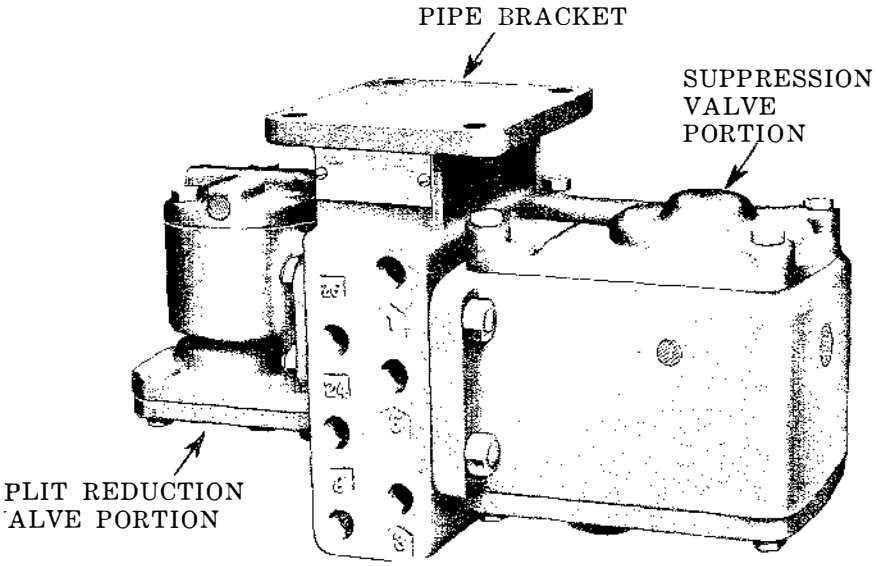


FIG. 27 C-1 SUPPRESSION VALVE

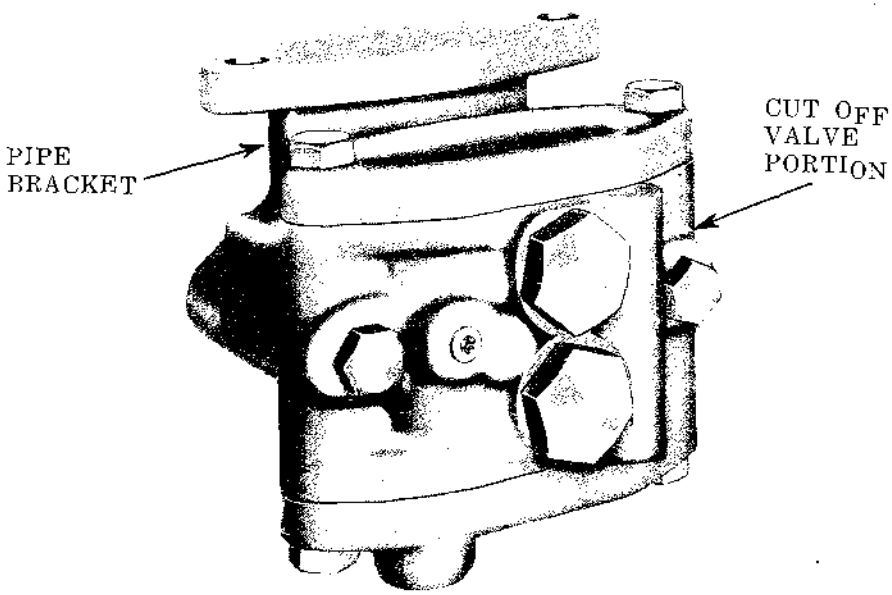


FIG. 28 A-1 CHARGING CUT-OFF PILOT VALVE

2. Delivers air pressure to a pressure switch which nullifies dynamic brake.
3. Delivers air pressure to a pressure switch which causes power to be cut off.
4. Delivers air pressure to initiate sanding for a specific time period (if so equipped).

b. The A-1 *charging cut-off* pilot valve operates when an emergency application occurs regardless of whether it was initiated from the 26-C automatic or emergency brake valve; or from an undesired separation of locomotive units or cars; or whether the emergency was initiated from the caboose brake valve or any other source.

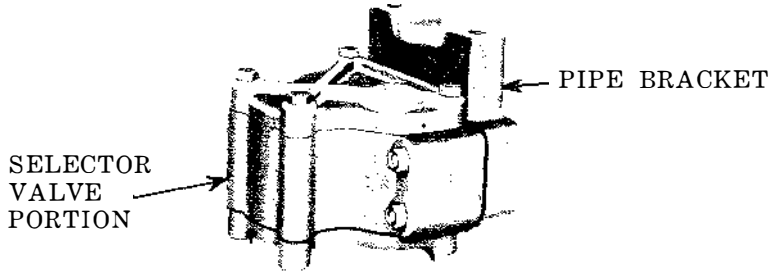


FIG. 29 F-1 SELECTOR VALVE

MULTIPLE UNIT CONTROL

On locomotives equipped for multiple uniting with older No. 6 and No. 14 types of brake equipment as well as 24-RL, the F-1 selector valve (Fig. 19) is also used. Primarily, it provides proper changeover of porting to allow a 26-L locomotive to respond properly to automatic and independent brake control from a lead locomotive having either the single pipe (6 and 14 types) or two pipe M.U. control (24-RL, 8-EL and 26-L).

Secondarily, the F-1 selector valve provides break-in-two protection against loss of brakes on trailing units in case of an undesired separation of locomotive units.

SANDING

Recent vintage diesel electric locomotives are equipped with two manual sanding switches in the locomotive cab. A lead truck sanding switch, which initiates sanding only at the leading axle of the leading unit in a locomotive consist, and a manual sanding switch which initiates sanding at the leading axle of each truck in the consist.

Sanding is automatically initiated during wheel slip and may also be initiated by emergency brake applications. Detailed description of sanding registers operation is in appendix pages

HANDBRAKE

On locomotives so equipped, hand brakes, parts, and connections must be inspected, and necessary repairs made as often as the service requires, with date being suitably stencilled or tagged.

UNIT BRAKE ARRANGEMENTS FOR LOCOMOTIVES

One of the more recent innovations in locomotive brake equipment is the "unitized" arrangement of 26-L Equipment. It provides a manifold on which are applied all the components of the 26-L Brake Equipment with the exception of the brake valve. This manifold is then mounted to a pipe bracket which is permanently located in the locomotive. All of the inter-valvular piping is in the form of cores in this manifold unit, which saves much time at installation. One of the big advantages of this system is that the manifold can be readily removed for periodic cleaning as a unit and tested as a unit. Also, all valves are easily accessible if an individual valve needs to be changed.

HANDLING LOCOMOTIVES DEAD IN TRAIN

So that a train brake application will cause the dead locomotive brakes to operate it is necessary to open the dead engine cock through which the main reservoirs can be charged from the brake pipe. This provides air pressure for the brake cylinder relay valve to put into the brake cylinders when the control valve calls for a service or emergency application. Because a locomotive has 3 to 4 times the braking ratio of a typical loaded freight car it is necessary to limit the maximum brake cylinder pressure to a low value when handling the locomotive dead. Otherwise the locomotive brake shoes and wheels will be severely overworked. If practicable it is better to couple the dead unit to the operating locomotive consist and connect the independent brake control pipes. Thus the dead unit brakes can be released by the controlling unit when a train automatic brake application is in effect.

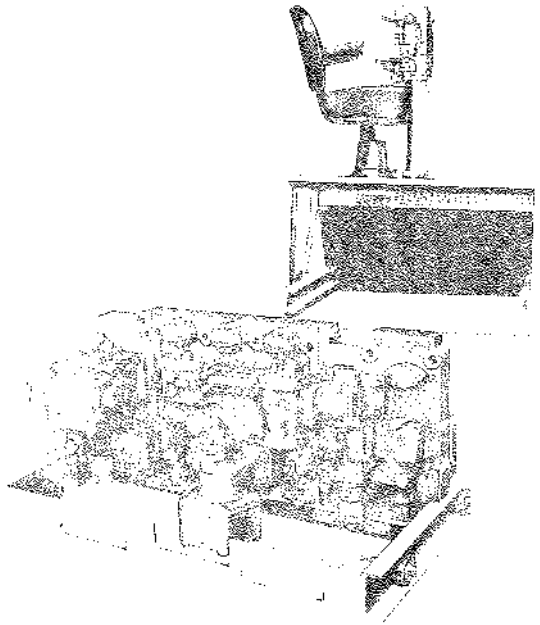


FIG. 30 WABCO—26-LU UNITIZED EQUIPMENT

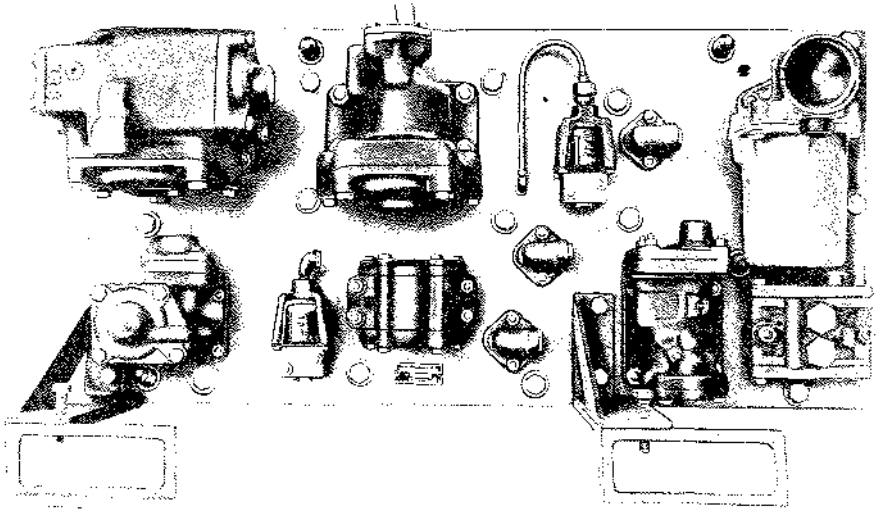


FIG. 31 NYAB PORTORACK

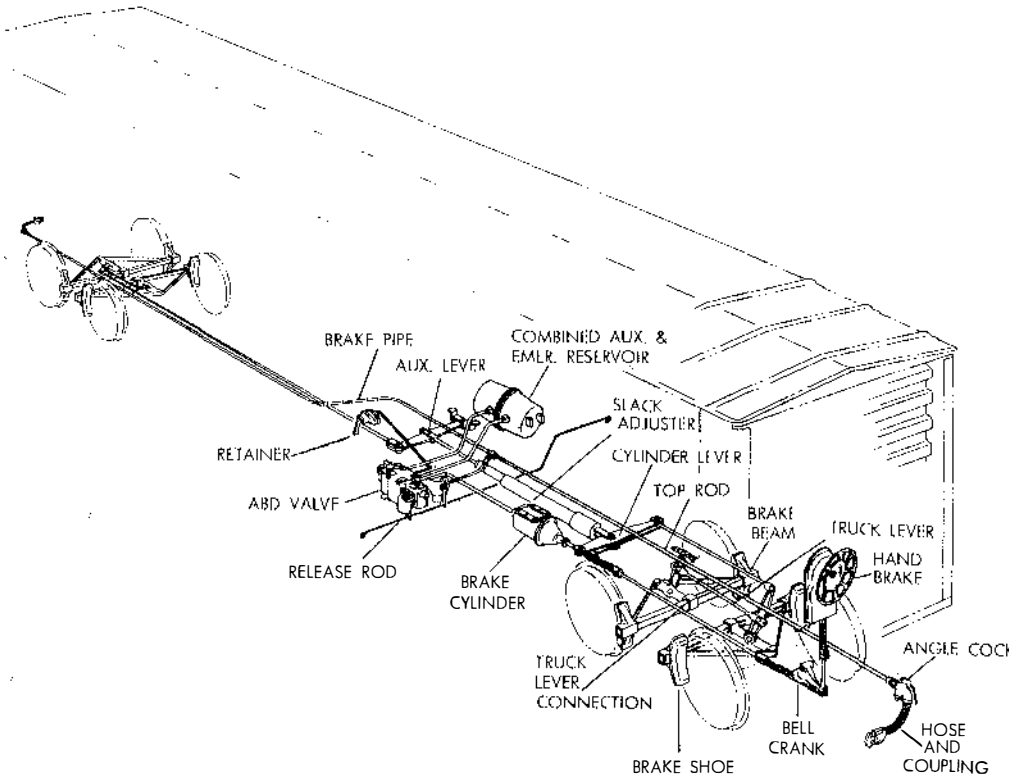
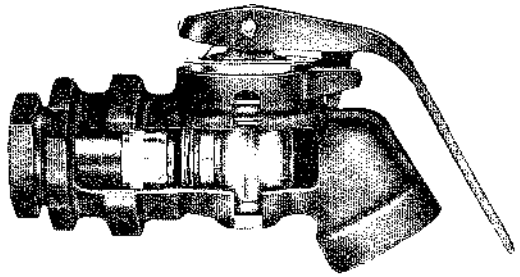


FIG. 32 TYPICAL ARRANGEMENT OF BRAKE EQUIPMENT ON A FREIGHT CAR

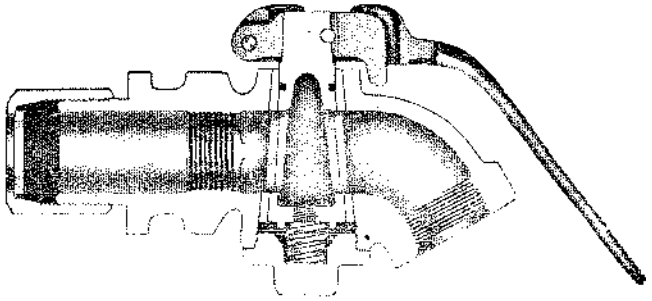
CAR BRAKE EQUIPMENT

Illustration Fig. 32 shows a typical arrangement of brake equipment on a freight car.

1. The brake pipe extends through each locomotive and car from one end of the train to the other. Between each locomotive unit and car brake pipe, end hoses and hose couplings make the flexible connections required. Each brake pipe end hose is usually connected to an angle cock, Fig. 33. The device is called an "angle cock" because the hose connection in one end is at an angle which allows the brake pipe end hose to droop downward at the proper angle in order to take a practical shape when coupled to the hose on an adjacent car or locomotive. Some long and cushioned underframe types of cars use brake pipe end cocks, usually with intermediate hoses and angle fittings.



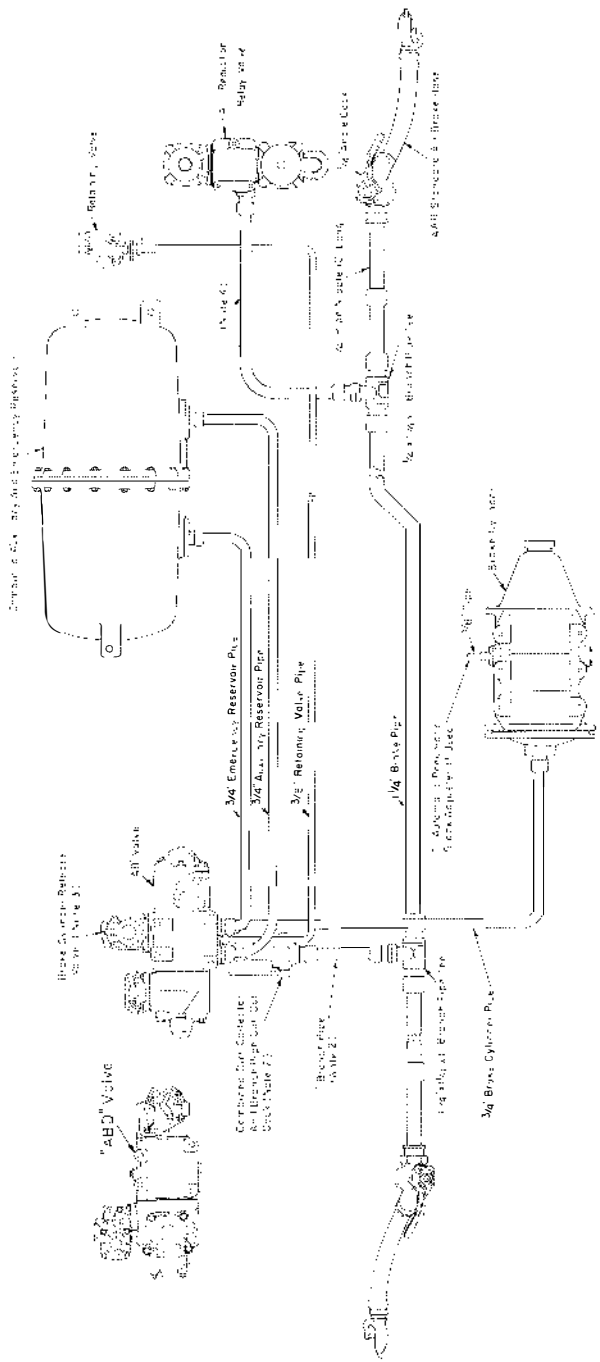
"BALL TYPE"



"PLUG TYPE"

FIG. 33 ANGLE COCKS

2. Referring to the schematic freight car piping illustrated in Fig. 34, there is a branch pipe from the brake pipe over to the control valve. Brake pipe air flows to and from the control valve through a combined dirt collector and branch pipe cut out cock. This device, Fig. 36, usually mounted to the control valve, allows the brake equipment on the car to be cut out in case of trouble without affecting the brake pipe pressure control to other cars.



TYPICAL "AB" TYPE FREIGHT BRAKE EQUIPMENT

FIG. 34

The handle of the branch pipe cut out cock is "down" or crosswise to the pipe when open (cut in) and parallel or in line with the pipe when closed (cut out).

The dirt collector portion provides a means for larger pieces of foreign material such as dirt, gravel and sand to be taken out of the air flow before reaching the control valve. It also provides a local sump to collect moisture which may be precipitated in the brake pipe.

3. The control valve on each freight car is of the AB or ABD type.
   a. The control valve receives air flow from the brake pipe and directs it to the auxiliary and emergency reservoir. During release and charging, reservoirs are "charged" and brake cylinder is connected to exhaust through the retaining valve.
   b. During a service brake application, the AB or ABD control valve directs air pressure from the auxiliary reservoir to the brake cylinder.
   c. During an emergency brake application, the AB or ABD control valve directs air pressure from both auxiliary and emergency reservoirs to the brake cylinder.
   d. There are two distinct portions of the AB and ABD valves both mounted to the pipe bracket. Fig. 34 shows top views of the AB or ABD valve. Fig. 35 shows the side views of AB and ABD valve.
      1. Part of the AB service portion, right hand side of figure 35-A is the reservoir release valve which is connected to the release valve rod extending to each side of the car. A separate brake cylinder release valve is mounted on the AB valve and usually is, also, connected to the release valve rod, although on some cars there is a second rod called the "Brake Cylinder Release Rod."
      2. On the ABD valve, Fig. 35-B, the reservoir release and brake cylinder release functions are combined in a single portion of the service portion called the release portion. A momentary pull of the rod to its full travel will start venting of brake cylinder pressure. After releasing the handle, the exhaust of brake cylinder pressure will continue. Pulling the rod all the way and holding it will also vent auxiliary and emergency reservoirs.
   e. The emergency portion is shown on the left of Figs. 35-A and 35-B of the AB and ABD valve illustrations. The emergency portion is used to detect when an emergency rate of brake pipe reduction has occurred. When the emergency portion goes into emergency position. it opens a large exhaust to locally vent the brake pipe pressure. This assists in transmitting the emergency reduction rapidly throughout the train. In emergency position, the emergency reservoir pressure is combined with auxiliary reservoir pressure and directed to the brake cylinder.

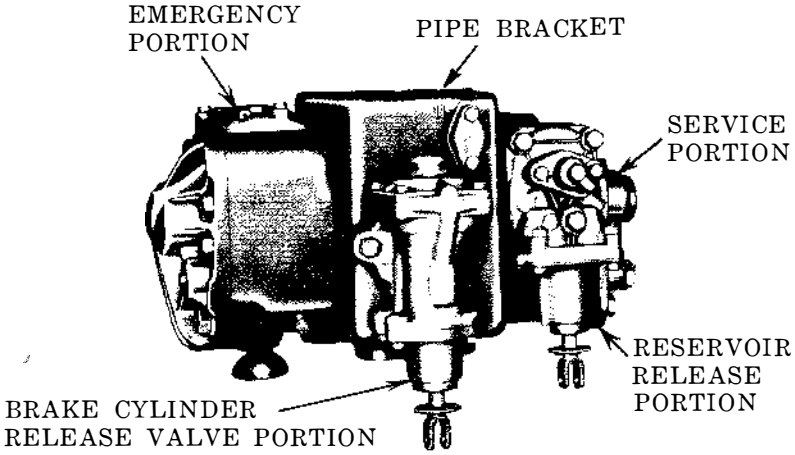


FIG. 35-A AB VALVE WITH QRB BRAKE CYLINDER RELEASE VALVE

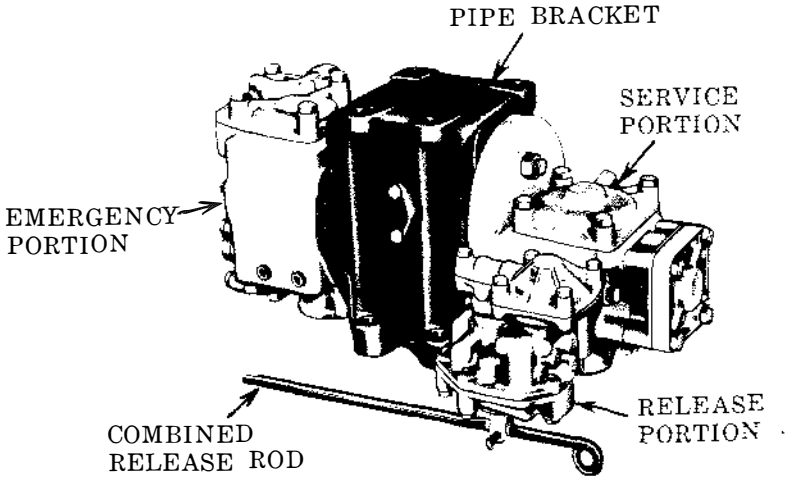


FIG. 35-B ABD VALVE

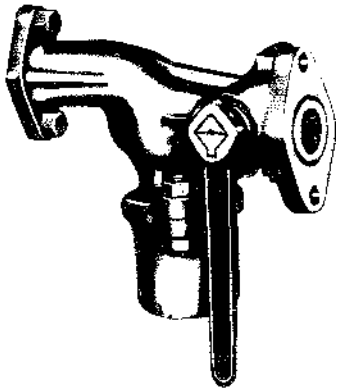
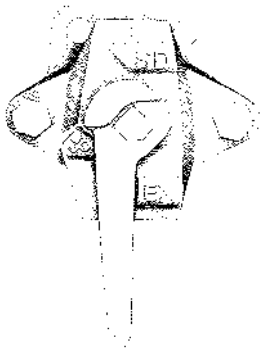


FIG. 36 COMBINED DIRT COLLECTOR AND CUT-OUT COCK

4. The retaining valves, Fig. 37, control the actual exhaust of brake cylinder air, when handle is moved to required position. The following compares control obtained when cars are equipped with former Standard 4-Position or NEW Standard 3-Position.
   a. Handle down - Direct Release "EX"—Same with either type.
   b. Handle 45° clockwise from "EX" - "HP" position, retains 20 psi in brake cylinder when brakes are released—Same with either type.
   c. Handle horizontal - 90° clockwise from "EX" - "LP" position, retains 10 psi in brake cylinder when brakes are released—This feature not provided in the New Standard 3-Position Type.
   d. Handle all the way up 135° clockwise from "EX" - "SD" or slow direct exhaust position, brake cylinder pressure is completely exhausted but at a slow rate—Same with either type.

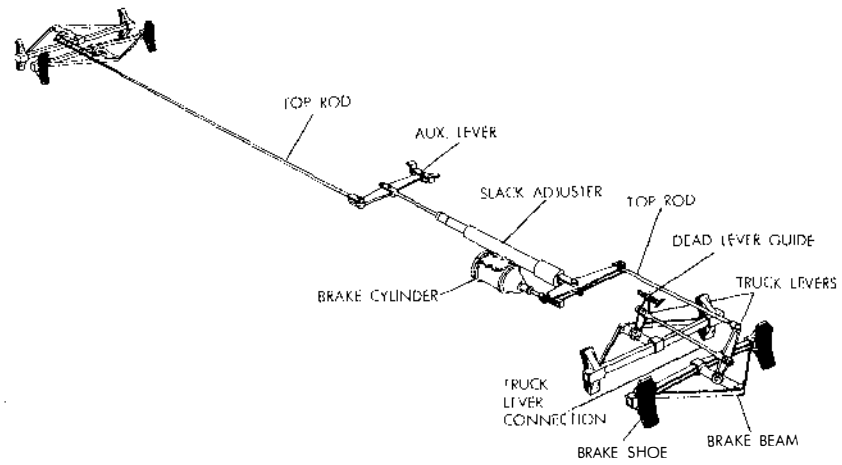
   Retainers are used in certain grade braking situations in order to retain sufficient retardation of the train to maintain speed control during the time the brake valve handle is in release position and car equipment is being recharged.

4-POSITION



3-POSITION

FIG. 37 RELEASE CONTROL RETAINERS



BOTTOM ROD THROUGH BOLSTER

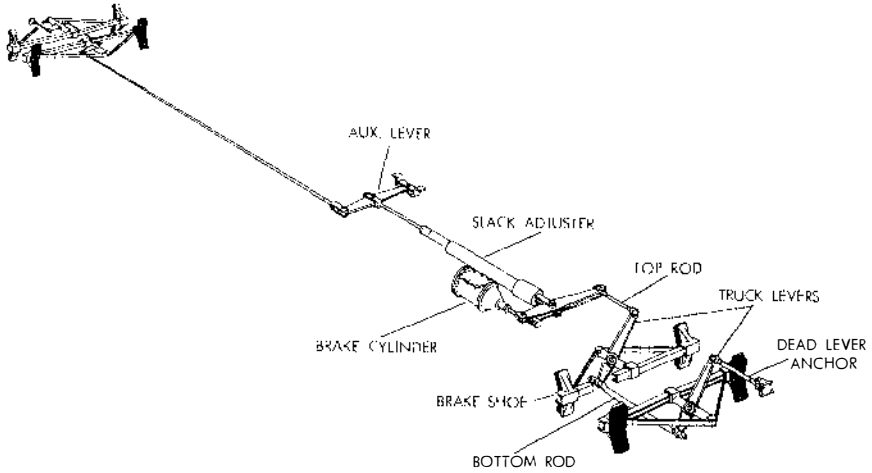
FIG. 38 CONVENTIONAL BRAKE RIGGING
BODY MOUNTED CYLINDER

5. The brake cylinder provides the force to push the brake shoes against the wheels. Usually, it is connected to a series of rods and levers called the foundation brake rigging which in turn move the brake beams (See Fig. 38-40). The brake beams have a brake shoe mounted on each side to contact both wheels on the axle. Some cars may have two or more cylinders, each operating a portion of the brake shoes. Normally, the cylinder force is multiplied by the brake rigging. The ratio of the braking force (the force of all the shoes operated from one cylinder) to the cylinder force is called the leverage ratio.

   For example:

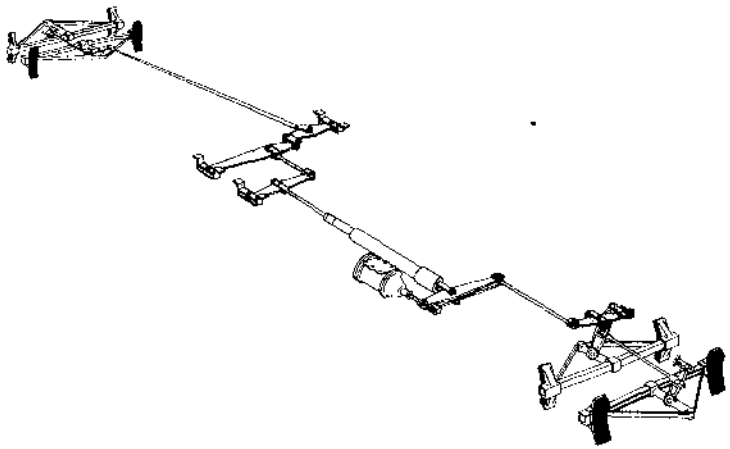
   $$\text{Leverage ratio} = \frac{\text{Total Shoe Force}}{\text{Cylinder force}} = \frac{40{,}000 \text{ lb.}}{4{,}000 \text{ lb.}} = \frac{10}{1} \text{ or } 10 \text{ to } 1$$

6. In some recent development, such as WABCOPAC or NYCOPAC, Fig. 41, the brake cylinder function is combined with the brake beam function and the cylinder force acts directly, without intermediate levers, to push the brake shoes against the wheels.
7. The brake shoes are replaceable blocks of wearable friction material held on the brake head by a "key". Brake shoes are of two general types based on the friction level they produce. For description REFER TO DEFINITIONS under "Brake Shoe".



BOTTOM ROD UNDER BOLSTER

FIG. 39



3 LEVER TRUCK RIGGING

FIG. 40

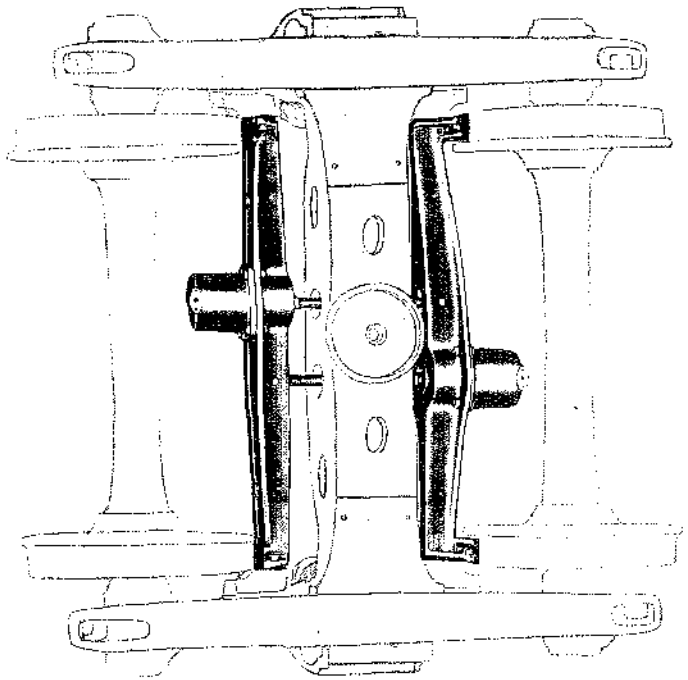


FIG. 41 WABCOPAC OR NYCOPAC TRUCK MOUNTED BRAKE ASSEMBLY

8. The brake equipment described above is called "single capacity" since the brake cylinder produces the same force whether a car is empty or loaded in any degree.
9. For cars having very light empty weights in relation to their loaded weights, it is necessary to use some form of load sensitive brake equipment in order to prevent severe overbraking and wheel sliding on empty cars. The two general forms of load sensitive brake equipment are:
   a. Empty Limiting Equipment, such as the L-1 Detector equipment, which holds the empty car brake cylinder pressure, and the braking force, to a specific amount such as 35 psi in service and 42 psi in emergency. These pressures will be the same regardless of whether the brake pipe pressure is 70 psi or greater.
   b. Empty-Load or Variable Load Equipment holds the empty car braking force to a specific proportion of that for the loaded car, such as 35%, 40%, 60%, etc. This means that the empty car will always have a close relationship to the proper amount of brake intensity on the train as a whole for any degree of application and at any brake pipe pressure.

Often when trains of very heavily loaded cars have to descend heavy grades, the loaded braking ratio has to be considerably higher than the minimum allowable. Thus the empty car braking ratio would be too high. Consequently, empty-load equipments are needed to keep empty car braking within practical limits while permitting high loaded car braking ratios.

Most load sensitive equipments automatically detect the load condition of the car by measuring the truck spring deflection. Some load sensitive equipments are of the manual type where a lever or handle must be properly positioned for empty or loaded car condition.

For a more detailed description of empty load type equipments see Chapter VIII, Technical Appendix.

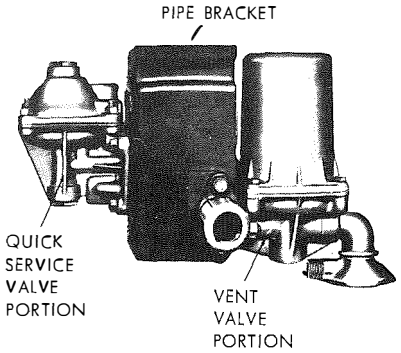


FIG. 42 A-1 REDUCTION RELAY VALVE

10. Freight cars with brake pipe over 75 feet long, between end hose couplings, should have an A-1 reduction relay valve added to the AB or ABD brake equipment. This valve assists in making service brake pipe reductions through the B-1 quick service valve portion shown on the left side of the pipe bracket, Fig. 42. Emergency applications are transmitted by the No. 8 vent valve portion, shown on the right hand side of the pipe bracket.

HAND BRAKES

Hand brakes on freight cars generally fall into three groups: a vertical wheel brake, a horizontal wheel brake (usually a drop shaft type), and a lever type brake.

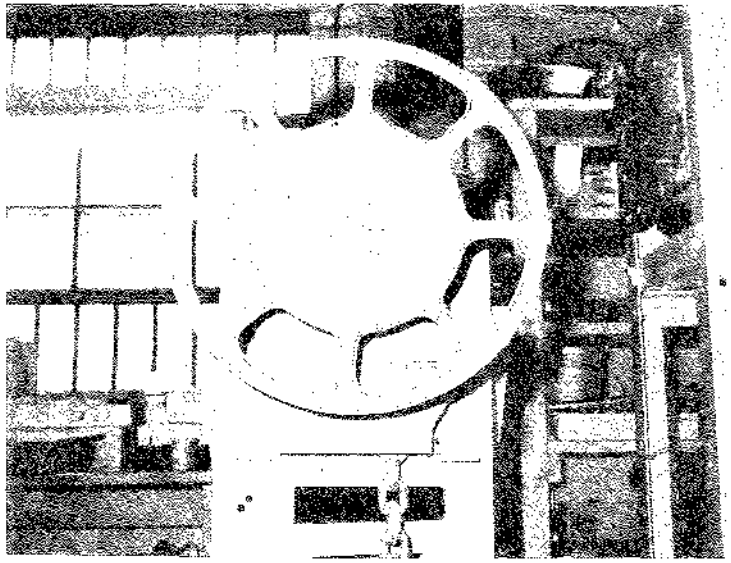


FIG. 43 AAR 1955 HAND BRAKE

FIG. 44 AAR 55 BELL CRANK FIG. 45 AAR 63 BELL CRANK

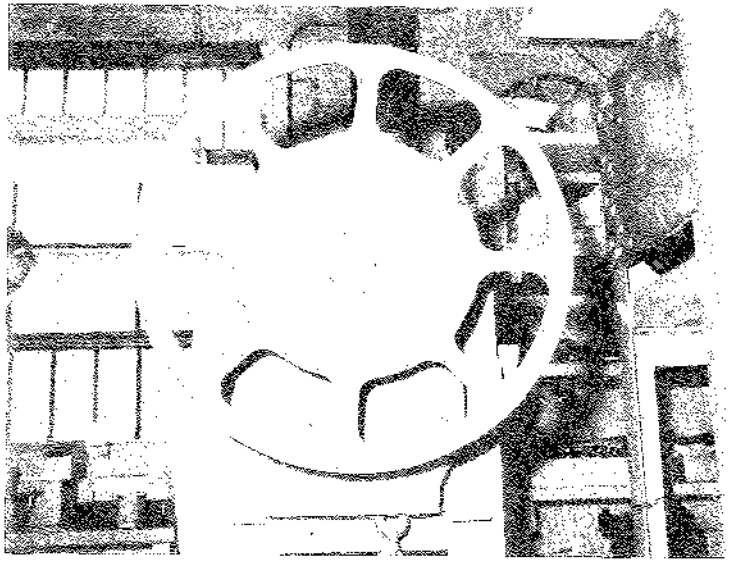


FIG. 46 AAR 1966 HAND BRAKE

FIG. 47 AAR 66 BELL CRANK

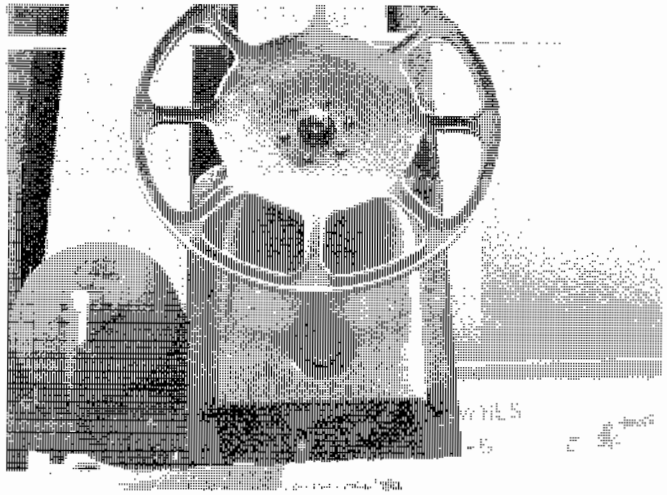


FIG. 48 AAR-HP HAND BRAKE

Vertical wheel:

There are three basic types of vertical wheel brakes. The AAR designation for each type must be cast or pressed into the face of the housing. Each type must develop not less than the certified force on the horizontal chain when the operator exerts a force of 125 lb on the rim of the hand brake wheel.

FIG. 49 AAR STANDARD SHEAVE WHEEL

1. AAR 1955 will develop 3925 lb with a 55 bell crank or 5000 lb with a 63 bell crank.
2. AAR 1966 will develop 4700 lb with a 66 bell crank.
3. AAR HP will develop 6250 lb with a sheave wheel.

Horizontal wheel:

A horizontal wheel type hand brake must develop not less than 3925 lb on the horizontal chain when the operator exerts 220 lb on the rim of the wheel. (No bell crank used.)

Lever type:

A lever type brake must develop not less than 3925 lb with a 55 bell crank when the operator exerts 125 lb on the handle at a point 14 in. from the centerline of the pinion.

AAR-S-63 designates a special design of brake for special types of cars where the standard types of brake cannot be used. These hand brakes must be replaced in kind. The S-63 designation can be applied to all groups, i.e., vertical wheel, lever, auxiliary power units, etc.

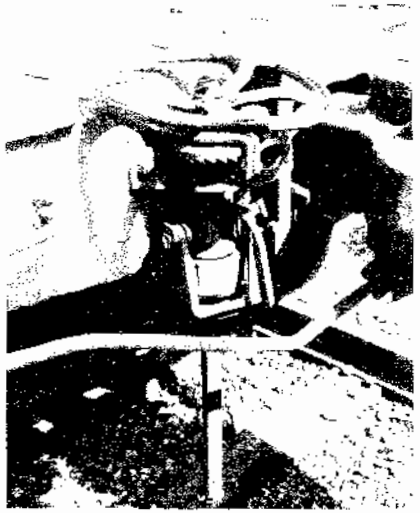


FIG. 50 DROP SHAFT HORIZONTAL WHEEL HAND BRAKE (WHEEL LOWERED)

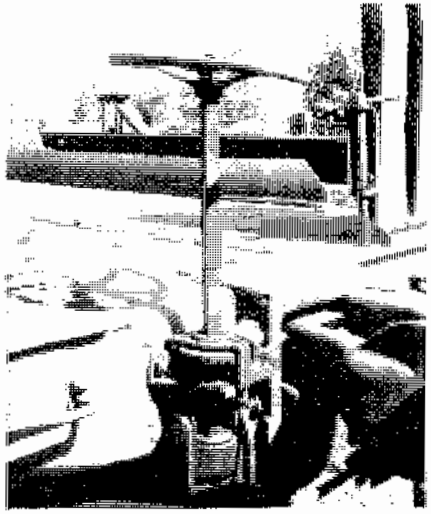


FIG. 51 (WHEEL RAISED)

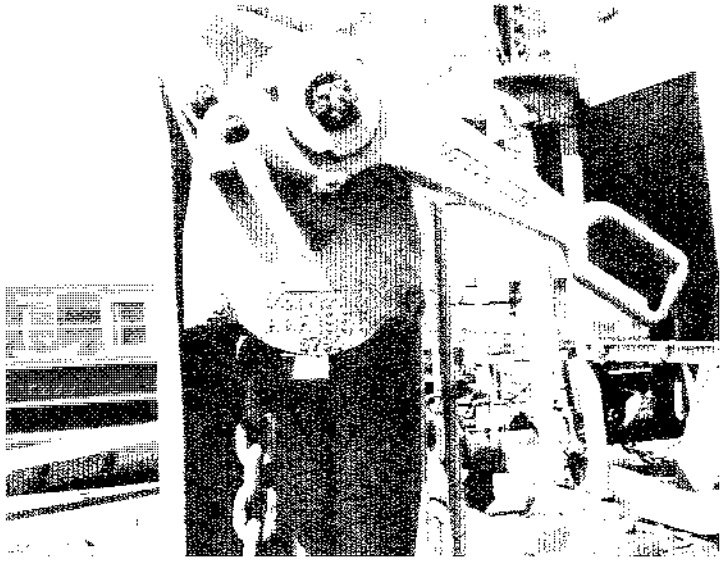


FIG. 52 AAR-1955 LEVER TYPE HAND BRAKE

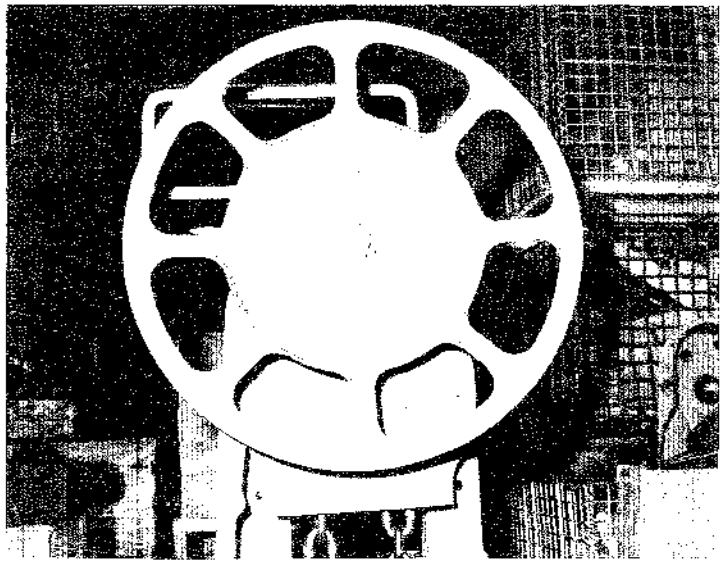


FIG. 53 AAR-S-63 HAND BRAKE

Holding Capacity of Hand Brakes:

The question is often asked, "How many cars must have the hand brake applied in order to hold a train or a cut of cars?" This question has many answers, since there are so many variables: i.e., weight of the cars, type of brake shoes, type of journal bearings, condition of rail and the amount of grade. The maximum holding capability would be obtained by setting every brake on every car. Since this is seldom necessary nor practical, the following has been prepared to offer a starting point for the number of brakes which must be set. It should be understood that there will be times when more brakes will have to be used.

Recommended Minimum Number of Hand Brakes
to be set according to Percent Grade

Percent Grade	Train of All Loaded Cars
1%	Set 1 of 4
2%	Set 1 of 3
3%	Set 1 of 2
4% or more	Set All

Hand brakes on railroad cars serve two purposes. Primarily, a hand brake is used as a parking or holding brake. For example, if a car is placed on a siding or at a warehouse door, the hand brake is used to hold a car at a particular spot when the locomotive is disconnected. Sometimes the hand brakes are used to assist the train crew to hold a train or control slack action while the pneumatic system is recharging to a safe level.

A hand brake also provides the means to control the speed of a car when a locomotive is not available, no air supply is available to charge the pneumatic system, and when it is necessary to move a car from one position to another.

Recommended Safe Practices in the Operation of Hand Brakes

1. Check rail conditions for moisture.
2. Observe lading for tonnage and type of load, keeping in mind the possibility of a surge of lading, load shift or overhanging loads.
3. When ascending or descending side ladders or end ladders of car, keep firm hand grip on ladder rungs and keep feet pointed toward either center or end of car.
4. Observe type and condition of hand brakes before applying or releasing hand brakes.
5. Before operating any type of hand brake on a grade, it should be tested; and, if defective, should not be used.

6. On staff or club brakes, standard brake clubs should be used in releasing or applying brakes, with stress applied toward car when possible.
7. On mechanical or power wheel brakes, clubs must not be used.
8. To apply or release the hand brake, use one hand only. Always keep one hand with firm grip on handhold, except on a horizontal wheel brake where two hands are required for safe operation.
9. With vertical wheel type hand brakes, turn the wheel clockwise with the right hand until slack is taken up; then give one or more short pulls on rim of wheel to secure desired braking power.
10. Always keep hands, body and clothing clear of spinning brake wheels or handles.
11. Never attempt to fully release any type of brake too close to derail, switch, or another car; it is safer to stop the car and slowly move the car toward derail or switch.
12. Never attempt to drop too many cars with one man; always secure asistance when grade characteristics warrant.
13. When releasing a hand brake, be sure to release the brake enough to permit slack in the hand brake chain.
14. Always make sure all hand brakes are released when a train is made up and ready to move to prevent wheel damage.
15. Since some cars have the hand brakes which operate only one truck and other cars have a hand brake on each truck all trucks should be examined to ensure that all brakes are released.

BRAKE RIGGING ADJUSTMENT — FREIGHT CAR

An area of braking which is often overlooked or lightly touched upon is rigging adjustment, especially in the truck levers. The modern innovation of an automatic double-acting slack adjuster will ensure that the proper piston travel is maintained. Proper piston travel is not an indication of the condition of the rest of the foundation brake rigging. Quite often the workmen will check the piston travel on the brake cylinder and, if this is correct, will not inspect the rest of the brake rigging for extreme angularity of the levers or interference between a brake lever and some other car component. Needless to say, either of these will seriously impair the effectiveness of a brake system.

There are five different basic types of brake system arrangements in the trucks. A brief description of each of these is:

1. "Bottom-Rod-Through," as the name indicates, has the bottom rod or truck lever connection passing through the truck bolster and is pinned to the center hole of the truck levers. The bottom holes of the truck levers are pinned to the brake beams. The top rod, which is pinned to the top of the live lever, must pass over the truck bolster to connect to a body lever. The top end of the dead lever is usually fulcrumed to the truck bolster. Figure 55 depicts the live lever of such an arrangement with bad angularity and approaching interference between the jaw of the top rod and the truck bolster. Figure 56 indicates an adjustment of one hole in the bottom rod to correct the condition and extend the wear cycle on this truck.

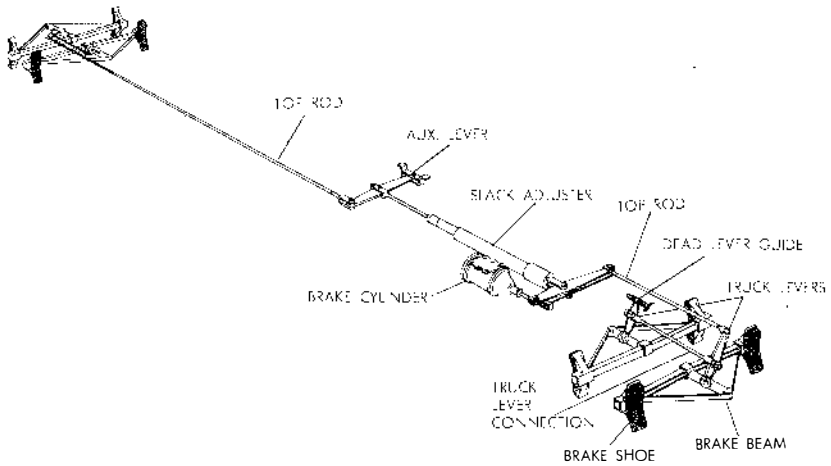


FIG. 54 BOTTOM ROD THROUGH BOLSTER BRAKE RIGGING

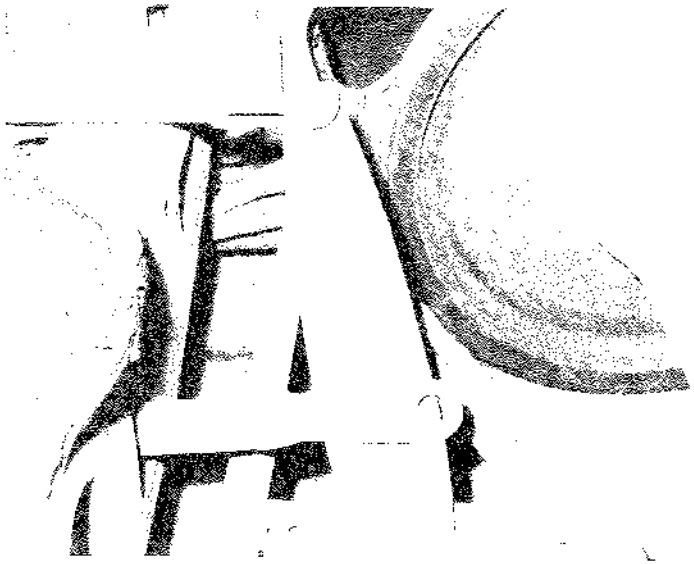


FIG. 55

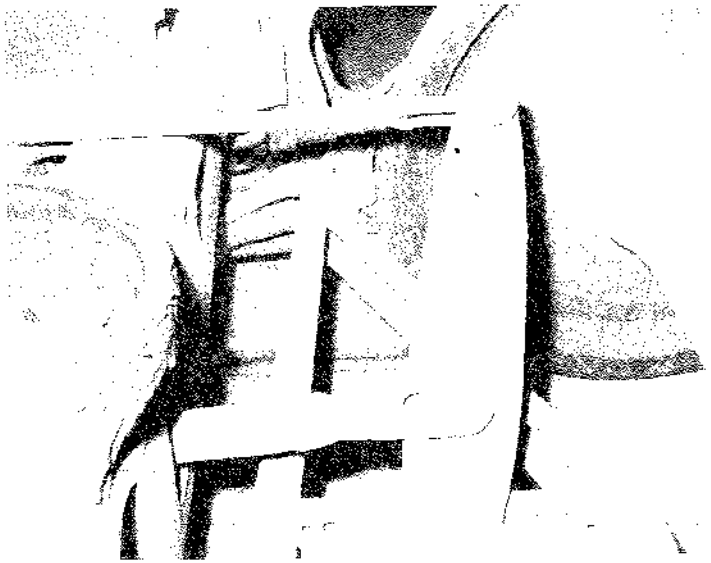


FIG. 56

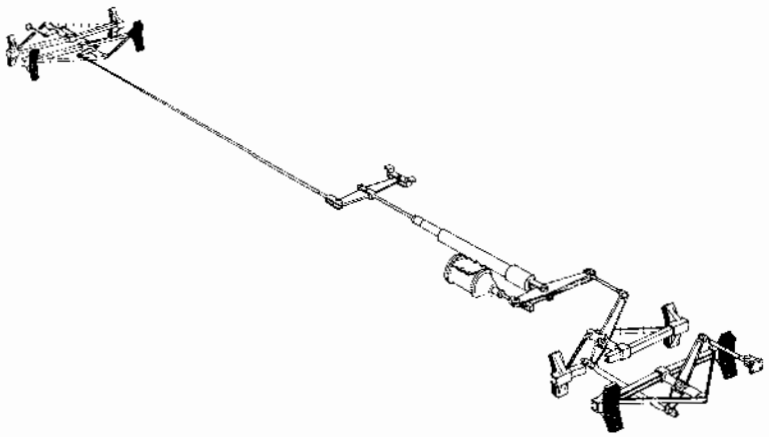


FIG. 59 BOTTOM ROD UNDER

2. "Bottom-Rod-Under" has the bottom rod passing under the truck bolster and pinned to the bottom holes of the truck levers. The center holes of the truck levers are pinned to the brake beams. The top rod connects the top of the live lever to the body lever. The dead lever is fulcrumed to the car body. Figure 57 depicts extreme angularity and approaching interference between the top rod and the axle. Figure 58 indicates an adjustment of one hole in the bottom rod to correct the condition.

FIG. 57

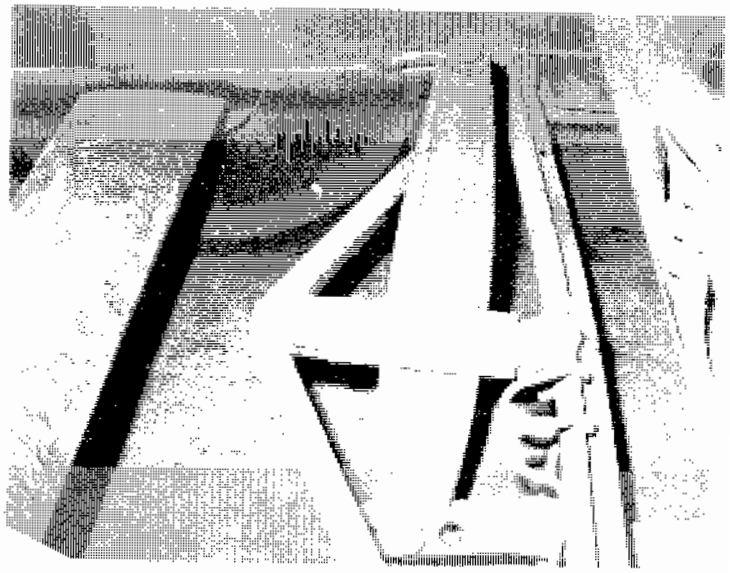


FIG. 58

3. "Three Lever Truck Arrangement" is basically a bottom-rod-through, except that the top of the live lever is connected to a horizontal lever which is fulcrumed on the truck bolster and is used to reverse the direction of pull. Figure 60 depicts this horizontal lever bottomed out on the truck bolster. Figure 61 shows the condition corrected with a one-hole adjustment on the bottom rod.

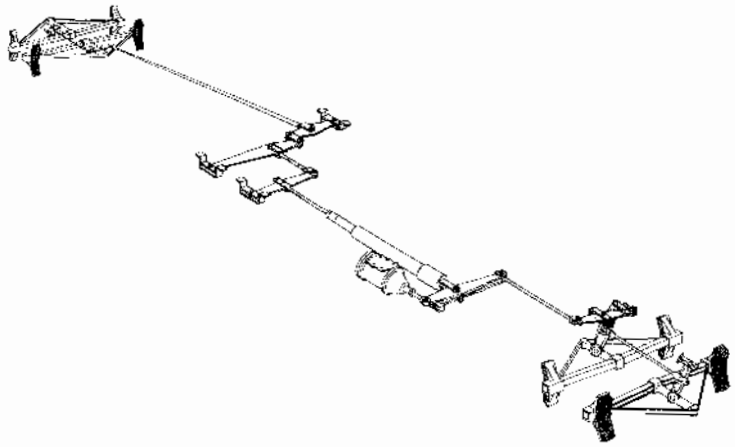


FIG. 59 3-LEVER TRUCK ARRANGEMENT

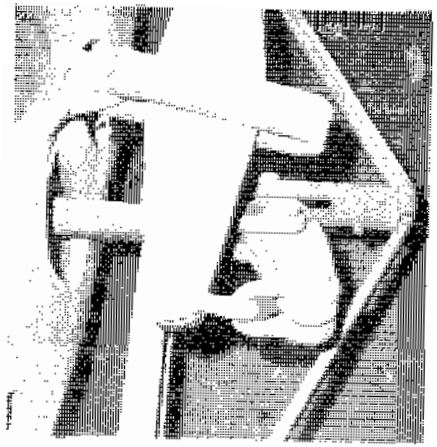


FIG. 60

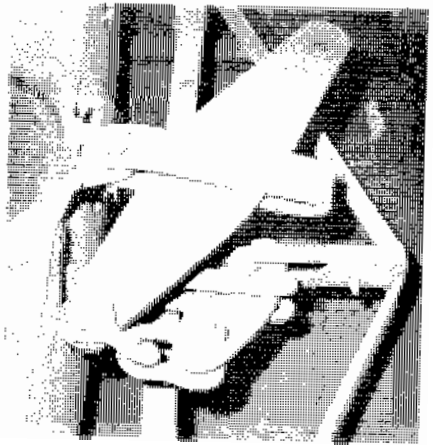


FIG. 61

4. The "Top-Rod-Under-the-Axle" or "Hook and Eye" arrangement is a contemporary design. The bottom rod passes through the truck bolster but is pinned to the top hole in the truck levers. The center hole of the truck levers is connected to the brake beam. The bottom end of the truck lever has a unique "hook" portion, and the rod which connect to them have an "eye" to complete the connection. The hook and eye replaces the traditional jaw and pin connection. The bottom of the live lever is connected to a vertical body lever with a rod which passes under the inboard axle. The vertical body lever also has the hook and eye connection. The bottom of the dead lever is connected to a vertical fulcrum lever with a rod which passes under the outboard axle. Figure 63 depicts the live lever bottomed out in the brake beam strut. Figure 64 shows the condition corrected with a one-hole adjustment on the bottom rod.

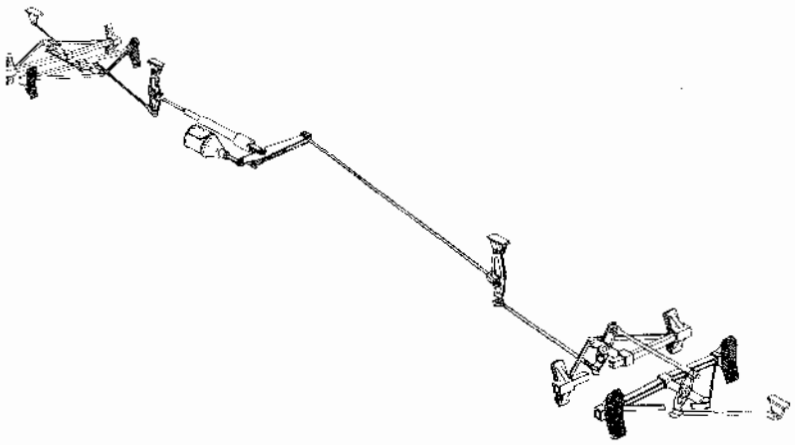


FIG. 62 TOP ROD UNDER HOOK & EYE

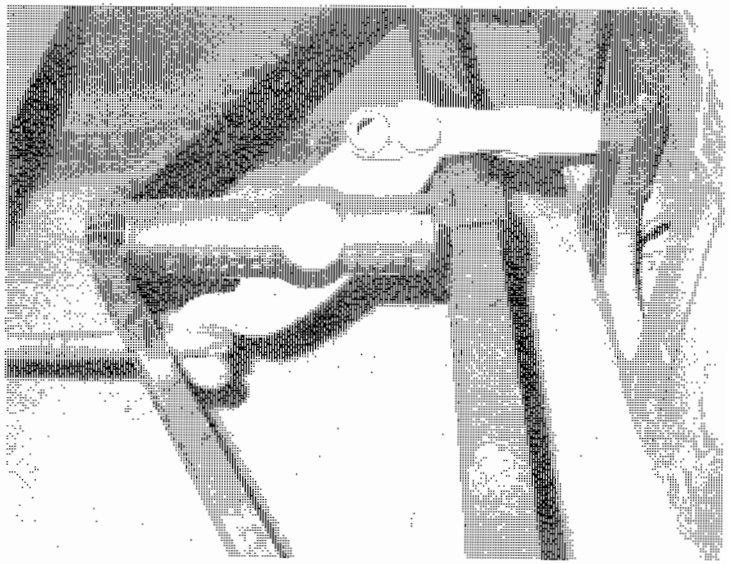


FIG. 63

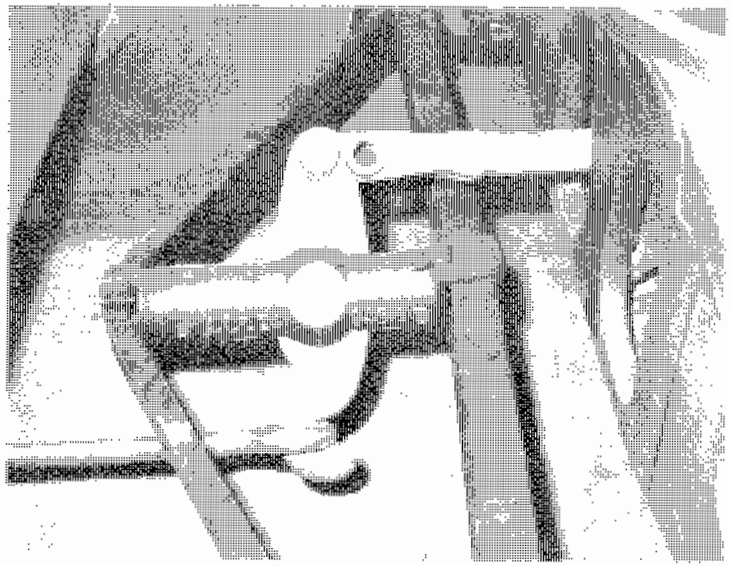


FIG. 64

5. Wabcopac-Nycopac truck mounted brake arrangements are a completely different concept from the previous arrangements. Each unit body includes a brake cylinder mounted on it, and the brake cylinder push rod is attached to the adjacent unit. This means that each cylinder is double acting and does not require the use of rods and levers for the air brake forces. The hand brake arrangement with this type of equipment does utilize rods and levers and usually operates on only one truck. The hand brake levers are basically the same as the "bottom-rod-under" (#2) described earlier. Figure 66 depicts the live hand brake lever after the wear cycle has advanced and shows the excess slack in the horizontal chain. Too much slack will allow the chain to rub on the axle and exceed the range of the bell crank. Figure 67 shows the condition corrected with a one-hole adjustment on the bottom rod.

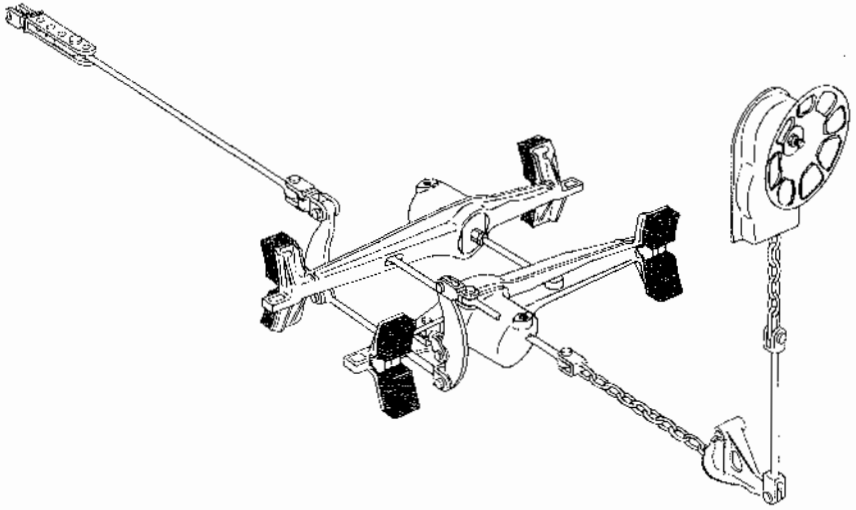


FIG. 65 WABCOPAC OR NYCOPAC

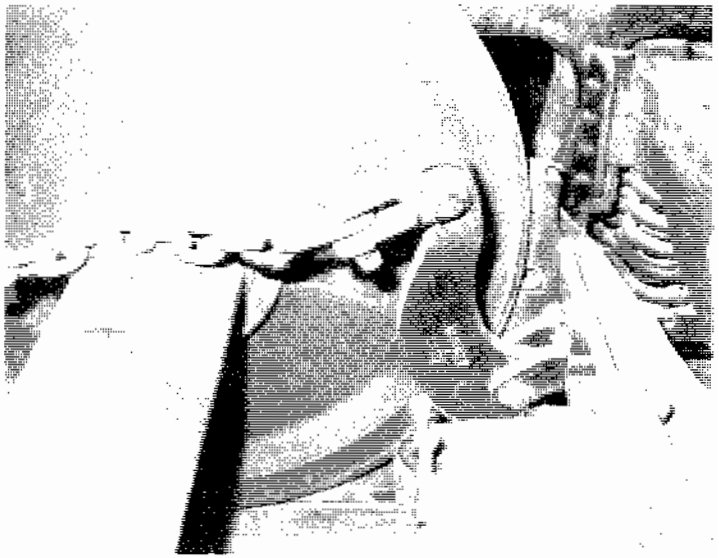


FIG. 66

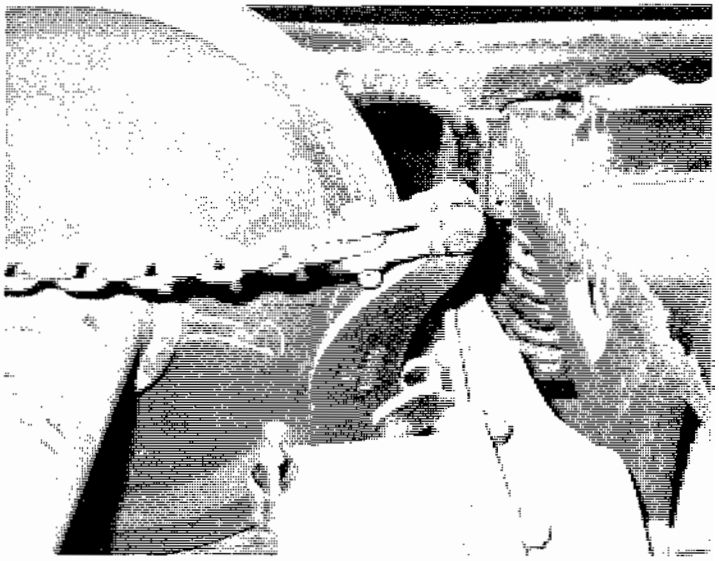


FIG. 67

CHAPTER III — TRAIN BRAKE SYSTEM OPERATION

General:

The train brake system for controlling the speed of the train on the road consists of:

a. First, the air brake on all cars and on the locomotive, is the primary and vital brake.

b. Second, the dynamic brake with which most locomotives are equipped.

Basic operating characteristics of the air brake and the dynamic brake are covered in this chapter. Emphasis in this section is on freight train operation. Passenger trains are covered in Section VI.

The major differences in freight and passenger brake operation lie in:

a. Train length. This brings about entirely different charging and brake application time characteristics.

b. Freight car brakes are only of the "direct release type" which cause an entirely different release characteristics.

c. Freight car braking levels or retardation abilities are lower than on passenger cars which means that considerably different brake operation is required.

Charging:

The primary source of power for the train air brakes is the compressed air stored in the reservoirs on each car. The train must first be charged in order for the air brake system to be operative. Charging takes time because the air has to pass from the locomotive via the brake pipe to charge each car to the required pressure.

Approximately 20 cubic feet of free air must be supplied to each car to charge it to 80 psi. Thus a 150 car train requires 3000 cubic feet of free air. In addition air to compensate for system leakage must be continually supplied. Car control valves are arranged with restricted charging chokes so the head end car equipment would not "rob all the air" from the brake pipe first. Tests and experience show that the best or fastest overall charging of the whole train and particularly the rear end is obtained with controlled charging rates as supplied with present equipment.

Figure 69 shows the typical charging time for trains from 50 to 150 cars with various degrees of brake pipe leakage. A single car will charge up to 80 psi in about 6 minutes. Note that trains up to 50 cars charge up to 80 psi in 7 to 9 minutes. 150 cars with 5 psi/min. brake pipe leakage will take about 46 minutes. System leakage, which includes all leaks in the brake equipment as well as the brake pipe (or train line) will increase the charging times. If the charging times of Fig. 68 are exceeded, excessive system leakage has developed. The cause of the leakage should be located and repaired.

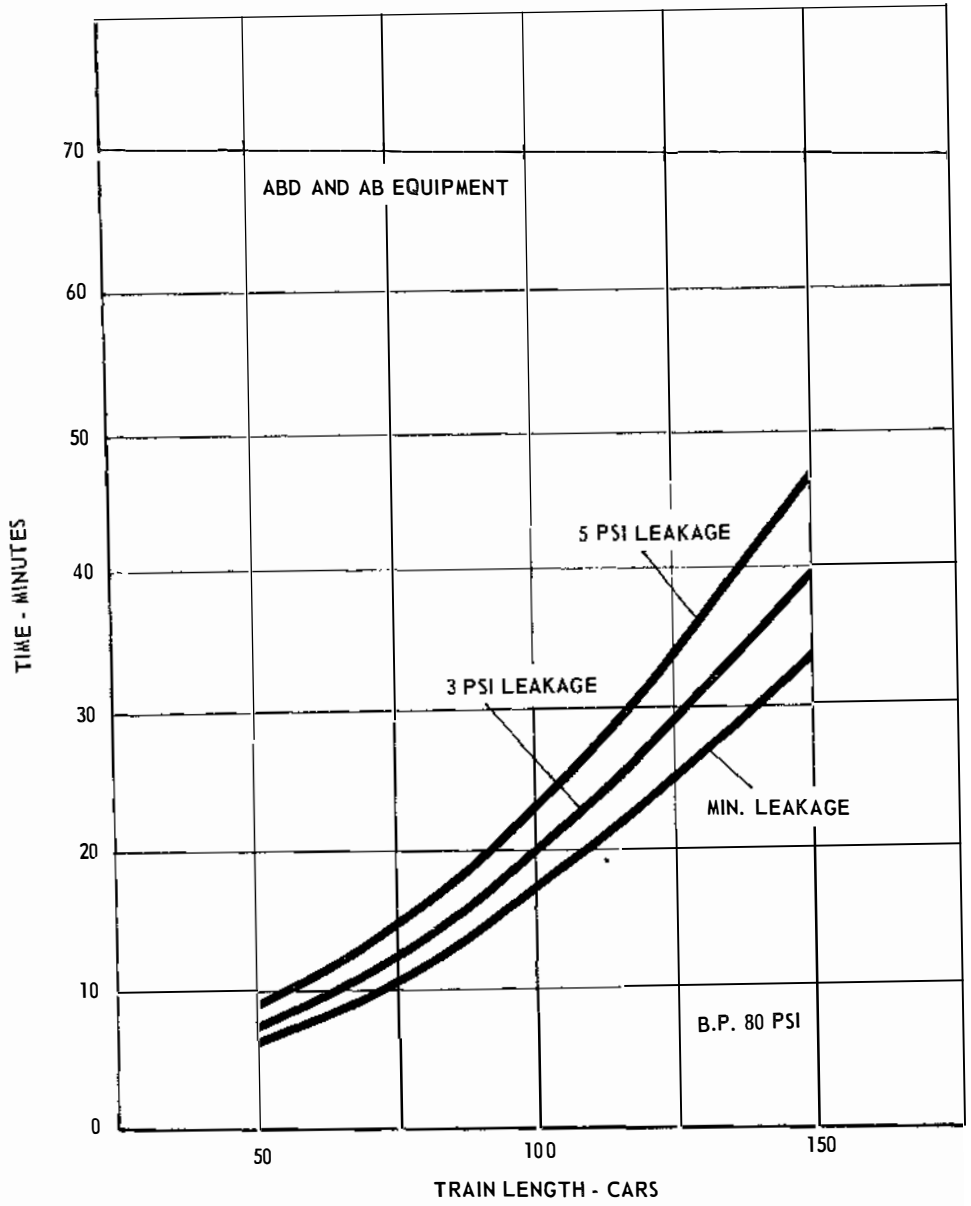


FIG. 68 CHARGING TIME WITH VARYING RATES OF BRAKE PIPE LEAKAGE

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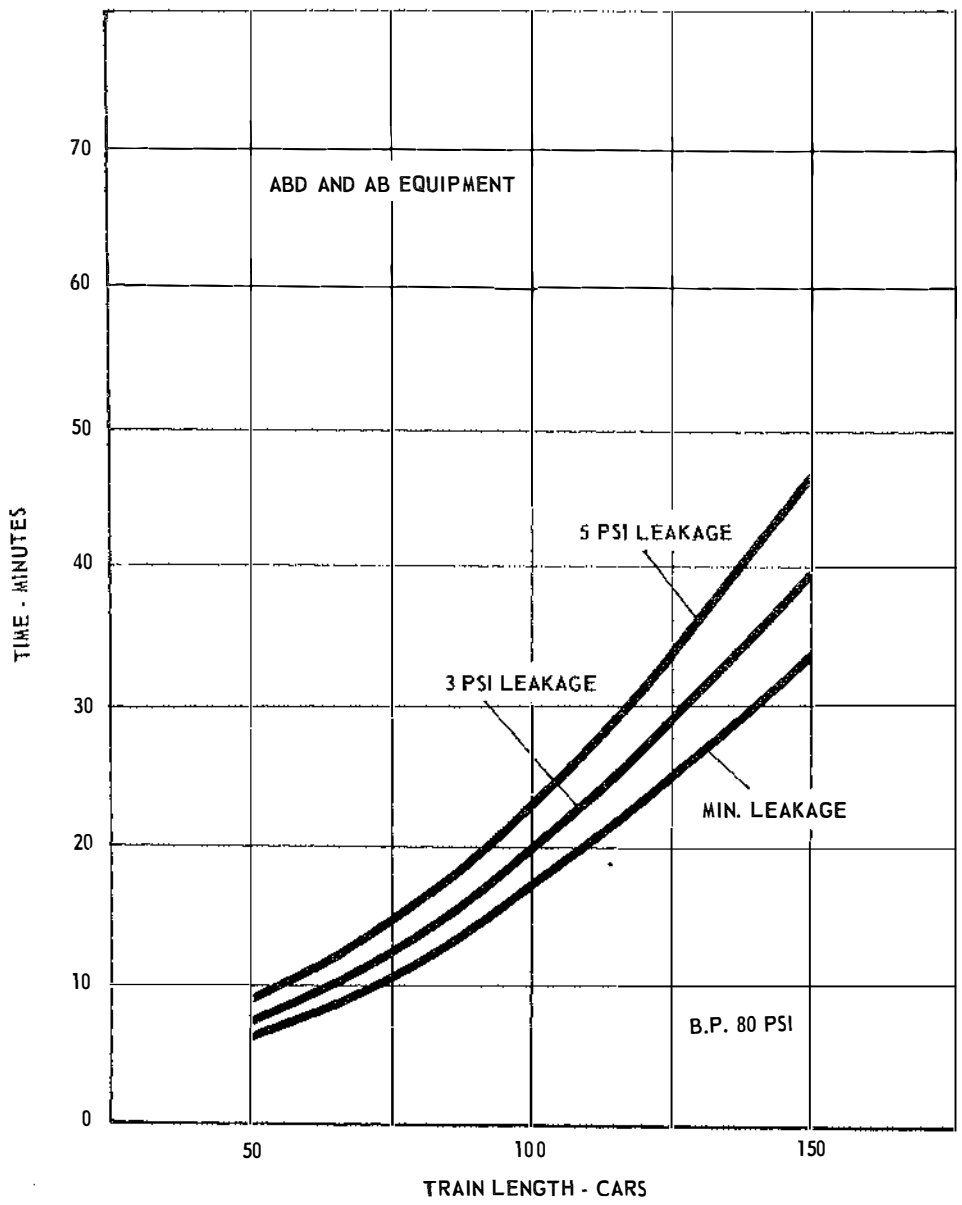


FIG. 68 CHARGING TIME WITH VARYING RATES OF BRAKE PIPE LEAKAGE

Service Brake Operation:

The development of the brake shoe retarding force is dependent on the rate at which brake cylinder pressure builds up within the train. Understanding the operation of the air brakes permits better train handling and the following curves illustrate brake cylinder pressure development with various length trains.

a. Figure 69 shows that a train of 50 cars, 50 ft. per car, with brake pipe length of 2500 feet on which a minimum brake pipe reduction of 6 psi has been made.
All brake cylinders have started to apply within 6 seconds after the application was initiated. Also, the brake cylinder pressure has built up within 22 seconds. Brake cylinder pressure on Car 1 and Car 50 is nearly the same at all times.

b. If an additional 25 cars is added to the original 50 cars for a total of 75 cars and 3750 feet of brake pipe, the following curve (Fig. 70 illustrates the brake cylinder build-up characteristics for the minimum brake pipe reduction of 6 psi.
The addition of 25 cars has lengthened the time for the last car to apply from 6 seconds with 50 cars to slightly under 10 seconds for the 75-car train. Note also that, although a larger difference in brake cylinder pressure exists between Car 1 and Car 75, Car 50 and Car 75 are very nearly equal as are the intermediate cars between Cars 50 and 75.

c. If an additional 25 car lots are added to total of 100-car train and 5000 feet of brake pipe, the 6-psi minimum reduction will produce brake cylinder pressure curves as shown in Figure 71.
The additional 25 cars have increased the time for the last car to apply to slightly over 12 seconds. Once again the rear portion of the train, from Car 50 to Car 100, shows very nearly the same pressures at all times.

d. Figure 73 illustrates brake cylinder build-up, in response to a 6 lb. minimum reduction on a 150 car train having 7500 feet of brake pipe.
The time for Car 150 to start to apply is 16 seconds. The brake cylinder pressure is still building up fairly uniformly throughout the train, as can be seen by the fact that very little pressure difference exists between Car 50 and Car 150.

We may, from Figures. 69, 70, 71 and 72, produce a curve of time to start application versus number of cars in the train for a 6-psi minimum brake pipe reduction. Figure 74 is such a plot. It permits us to judge when the last car of a train will begin to apply and thus presents information which can aid in understanding train operation.

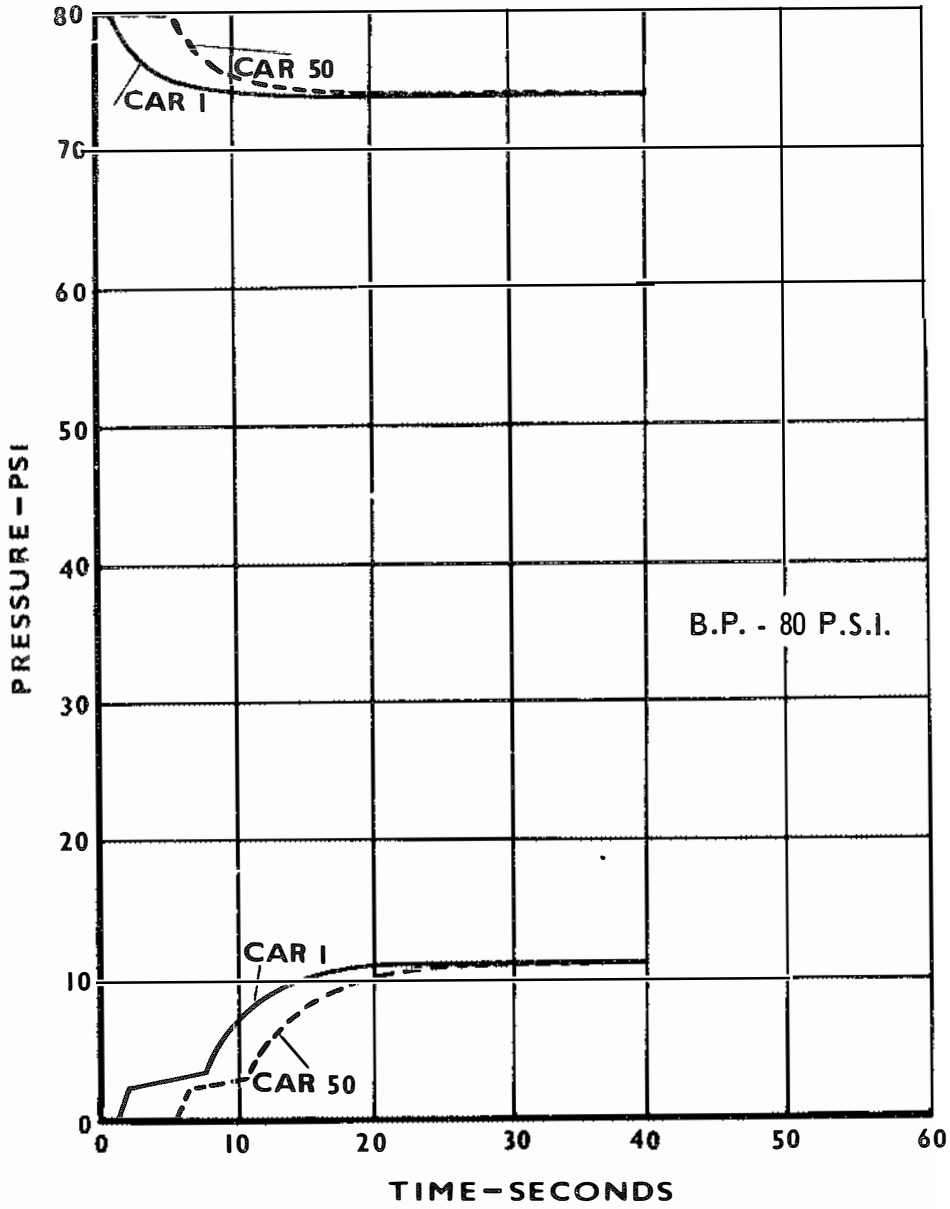


FIG. 69 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 6 PSI B.P. REDUCTION, 50-CAR TRAIN

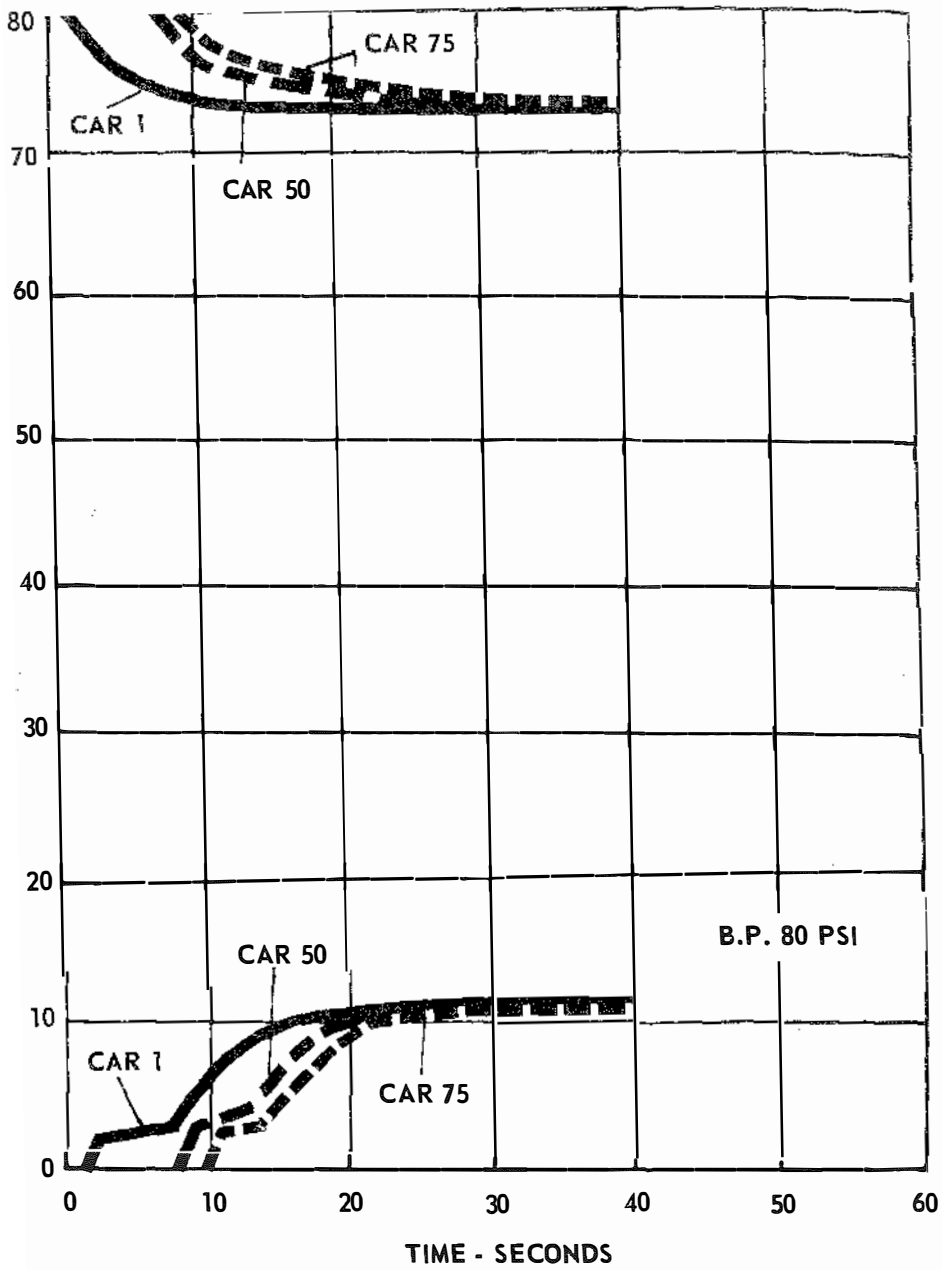


FIG. 70 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 6 PSI B.P. REDUCTION, 75-CAR TRAIN

For a heavier brake application such as that produced by a 15-psi service reduction, Figs. 74 through 77 illustrate the brake cylinder buildup on trains of 50, 75, 100 and 150 cars.

Note that the time for the last car to start to apply is the same as was obtained for the 6-psi reduction on a train of the same length. The time required is independent of the extent of the reduction since it is related to the quick service function of the control valves on the cars.

Also, the rate of development of brake cylinder pressure is proportional to the rate at which the brake pipe pressure falls on each of the cars in the train.

Modern railroading dictates longer lengths than the 50-ft. cars used in the previous examples. The next examples involve cars which are 85 feet long and have nominally 100 feet of brake pipe length.

The brake cylinder pressure build up for a full service application using 80 psi brake pipe pressure on a train of 75 cars each being 50 ft. long (3750 ft. of brake pipe) is shown in Figure 78.

Figure 79, shows the same reduction on a train of 75 cars havng 7500 ft. of brake pipe.

The time required to develop brake cylinder pressure on the rear of the longer train of 75 cars, 100 feet each in length, is twice that of the 75 car train of 50 foot cars. Also, the difference at any time between the brake cylinder pressure on the first car of the train and last car of the train is much greater for the train of longer cars.

Modern freight brake equipment is available to materially reduce the length of time for a brake pipe reduction on a train of long cars. The A-1 reduction relay valve incorporates continuous quick service, that is, brake pipe is reduced locally at each car equipped at a controlled rate to aid the locomotives brake valve in making the brake pipe reduction.

Figure 80 is the brake cylinder pressure development for the same train as shown in Figure 79, except that the train is equipped with A-1 Reduction Relay Valves.

A comparison of Figure 80 with Figure 78 shows that the development of brake cylinder pressure is virtually the same for the two trains even though the total train length is double for the train of long cars.

The improved response of train brake cylinder pressure on the train of long cars with A-1 reduction relays is beneficial in two respects. First, the temporary difference in train braking during the reduction reduces the tendency for rapid slack changes. Secondly, the faster development of brake cylinder pressure will result in shorter stopping distances.

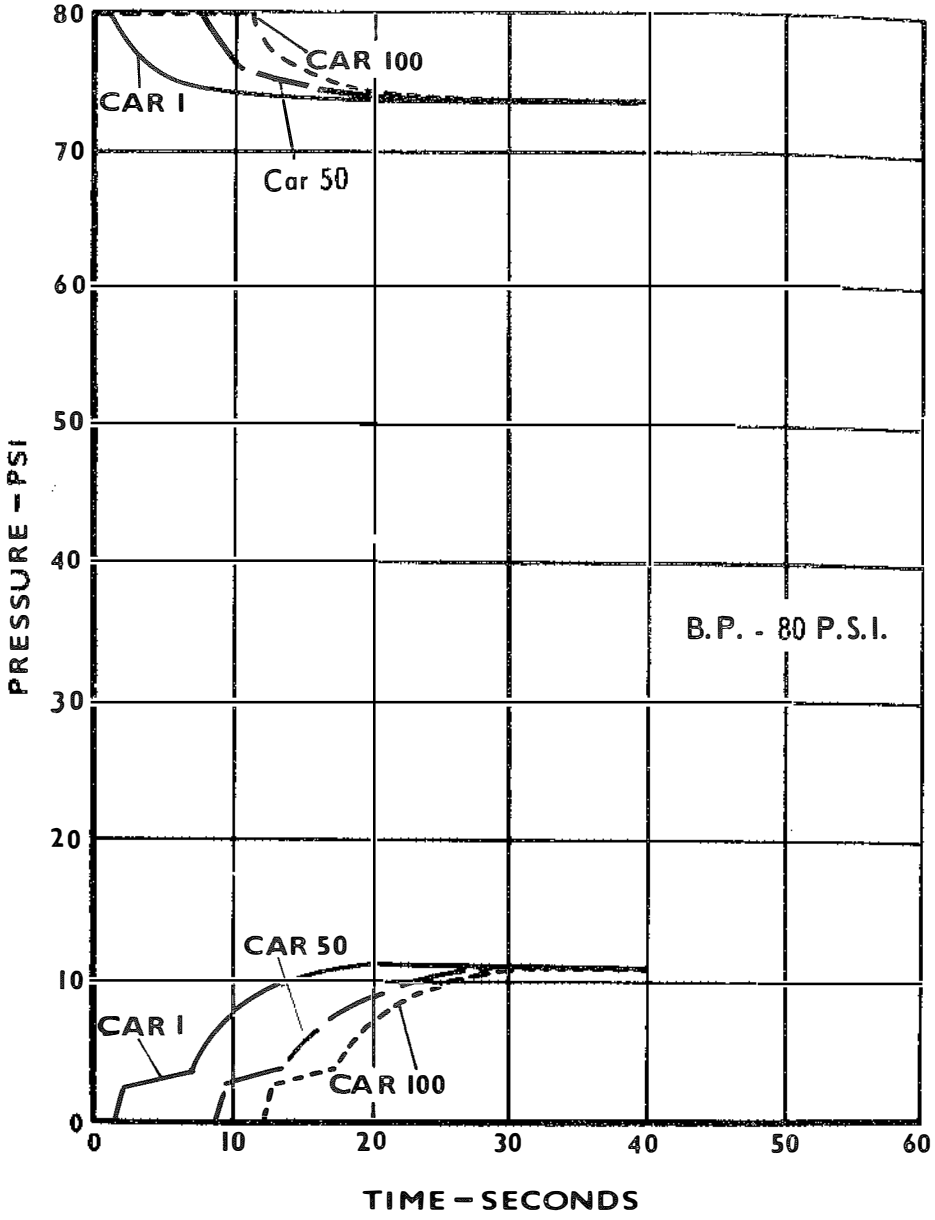


FIG. 71 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 6-PSI B.P. REDUCTION, 100-CAR TRAIN

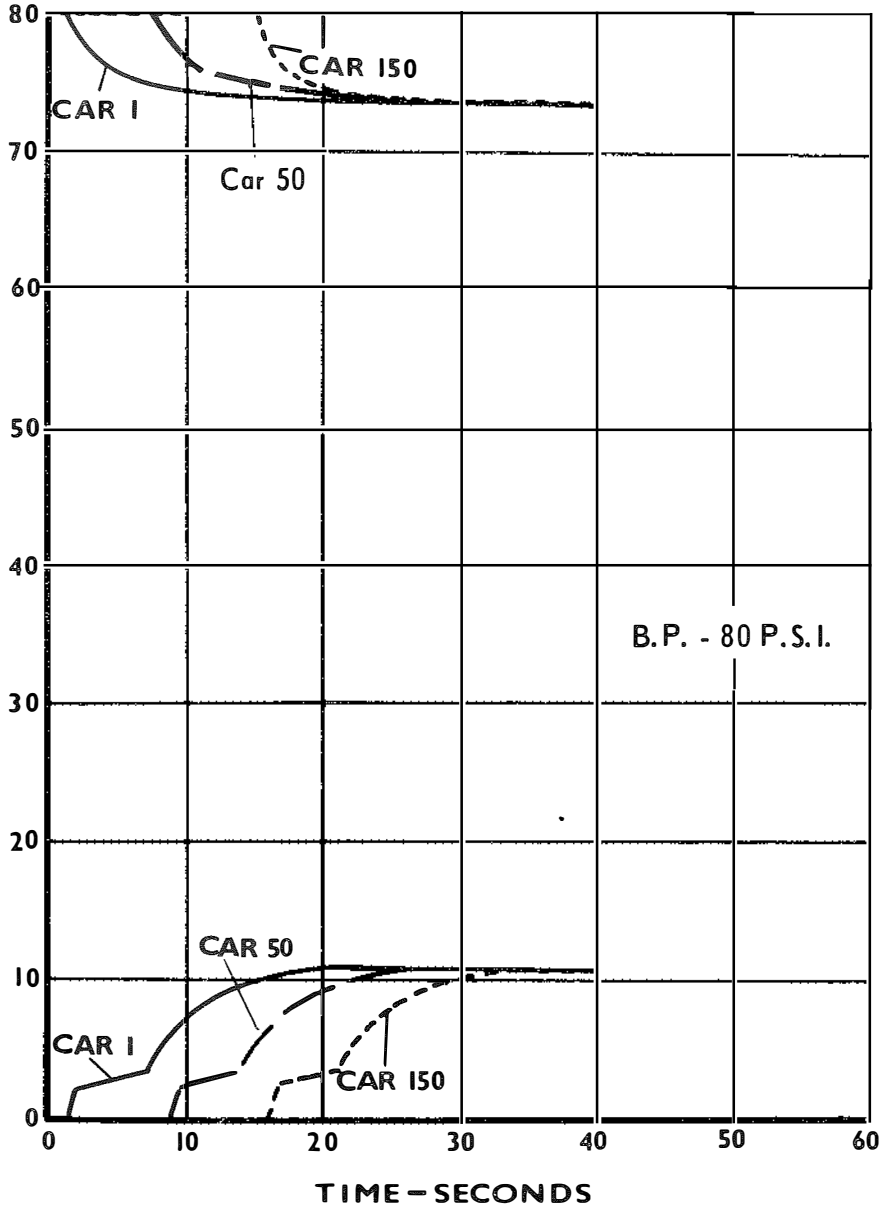


FIG. 72 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 6-PSI B.P. REDUCTION, 150-CAR TRAIN

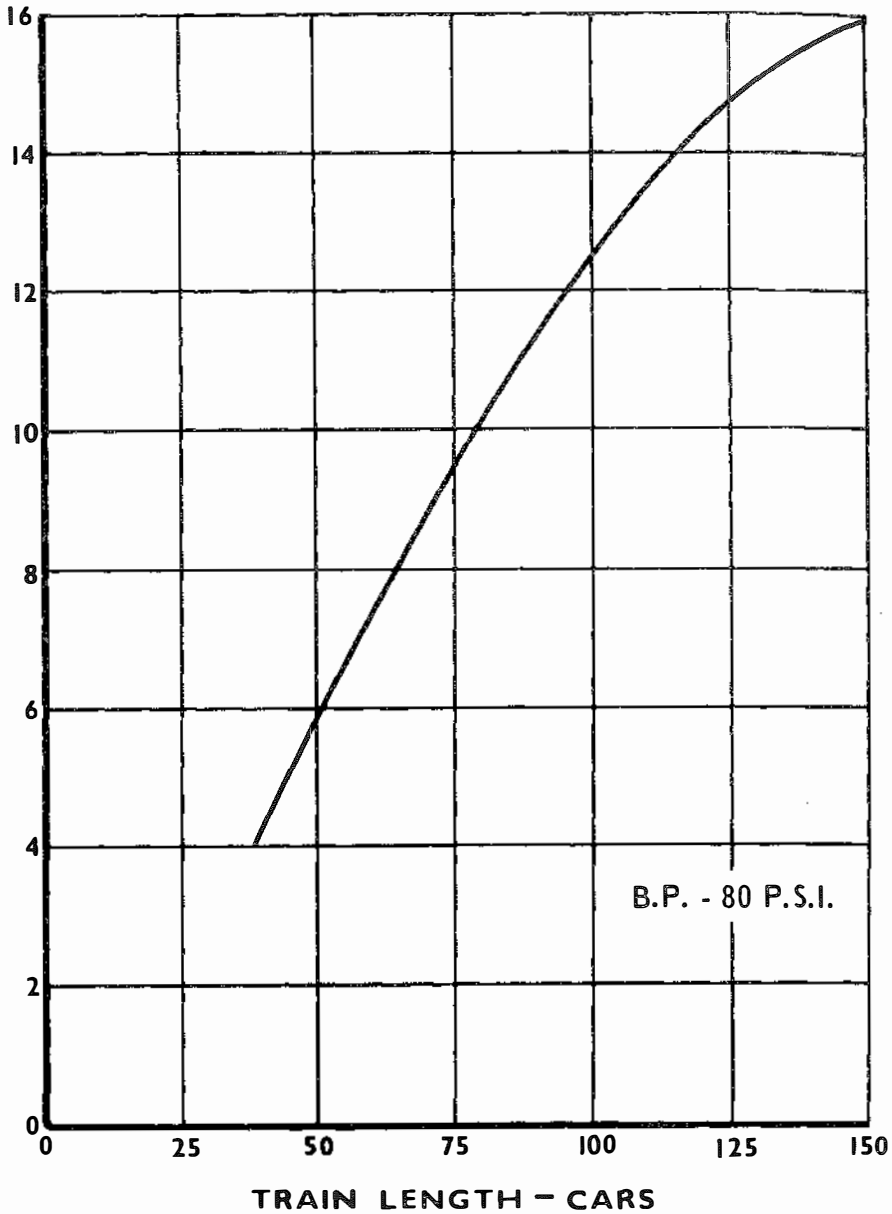


FIG. 73 TIME TO INITIATE BRAKE CYLINDER PRESSURE ON LAST CAR OF TRAIN, 6-PSI B.P. REDUCTION

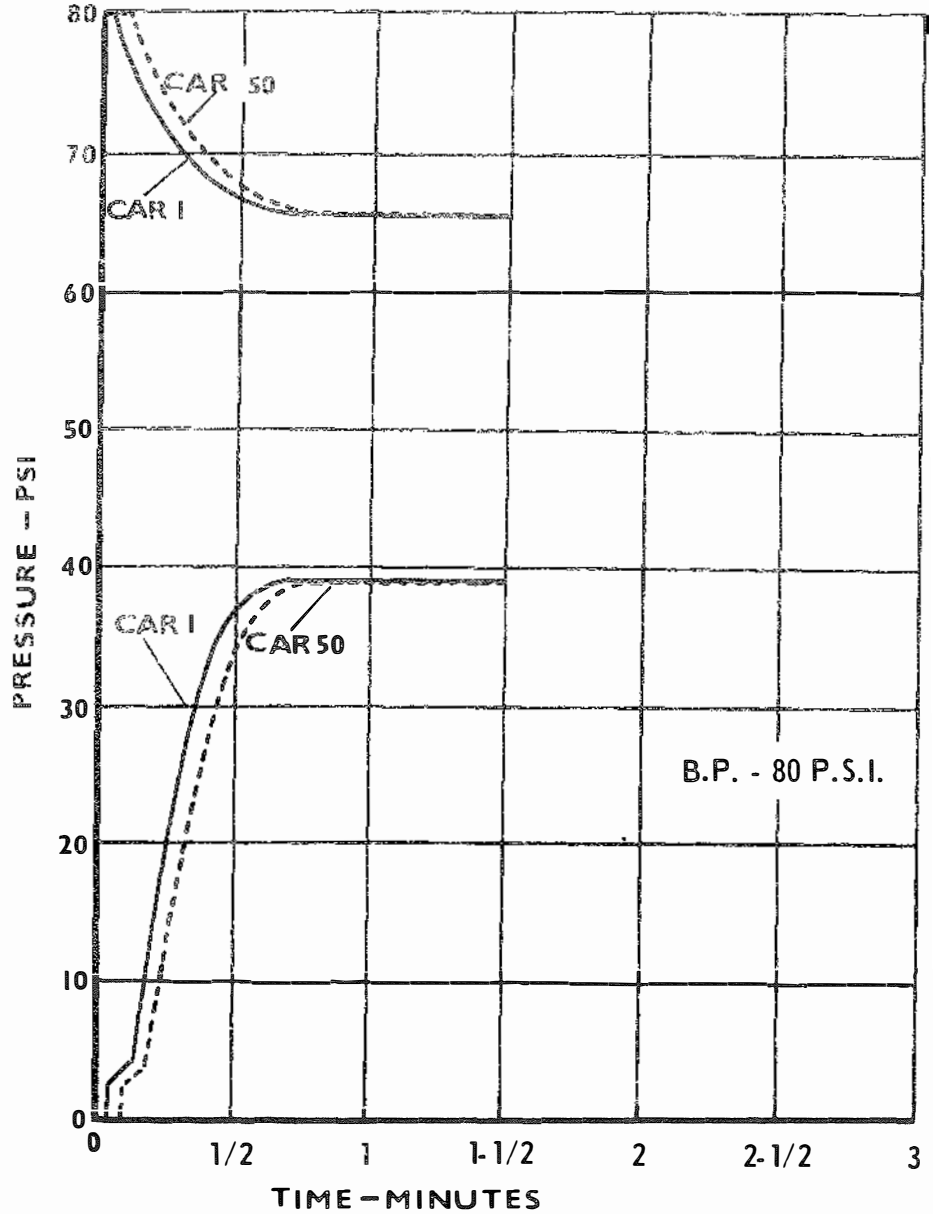


FIG. 74 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 15-PSI B.P. REDUCTION, 50-CAR TRAIN

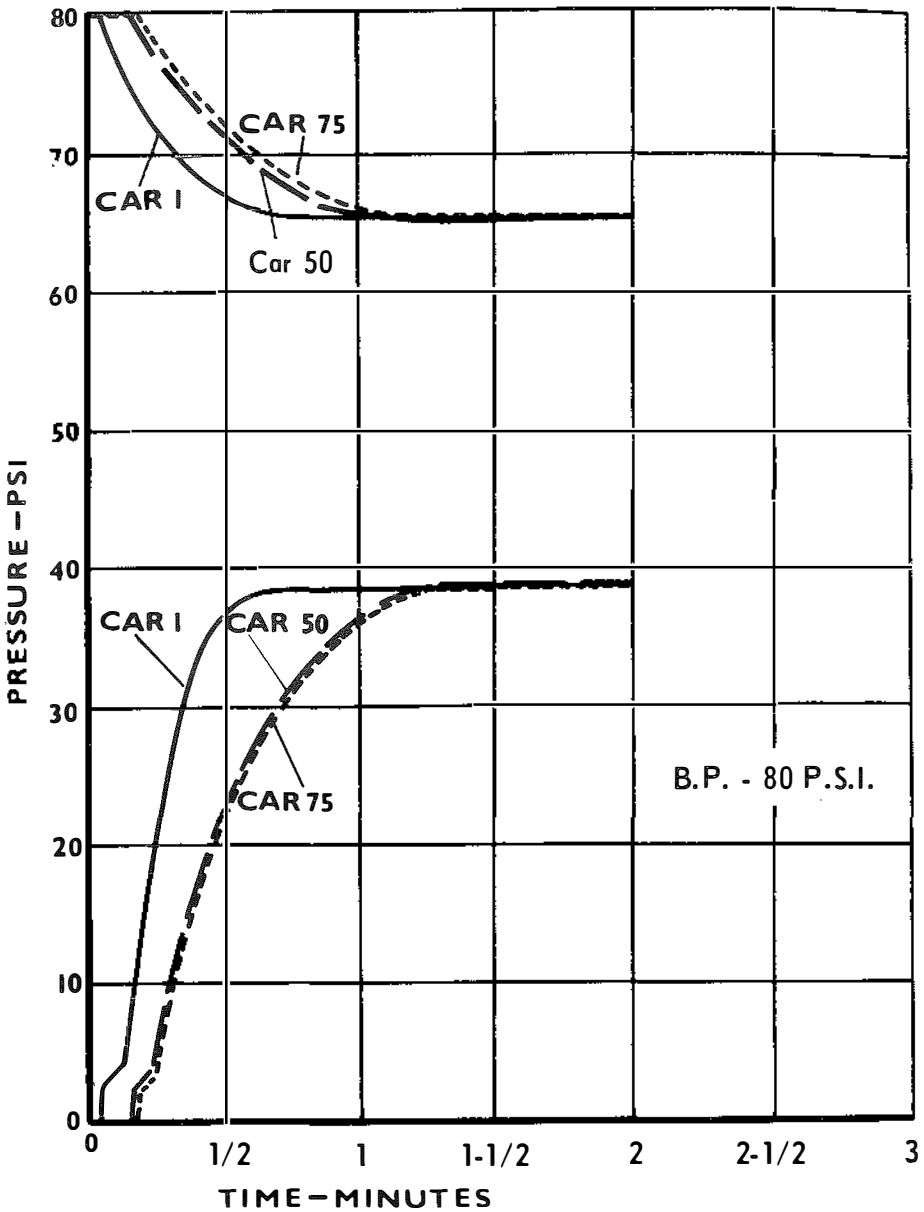


FIG. 75 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 15-PSI B.P. REDUCTION, 75-CAR TRAIN

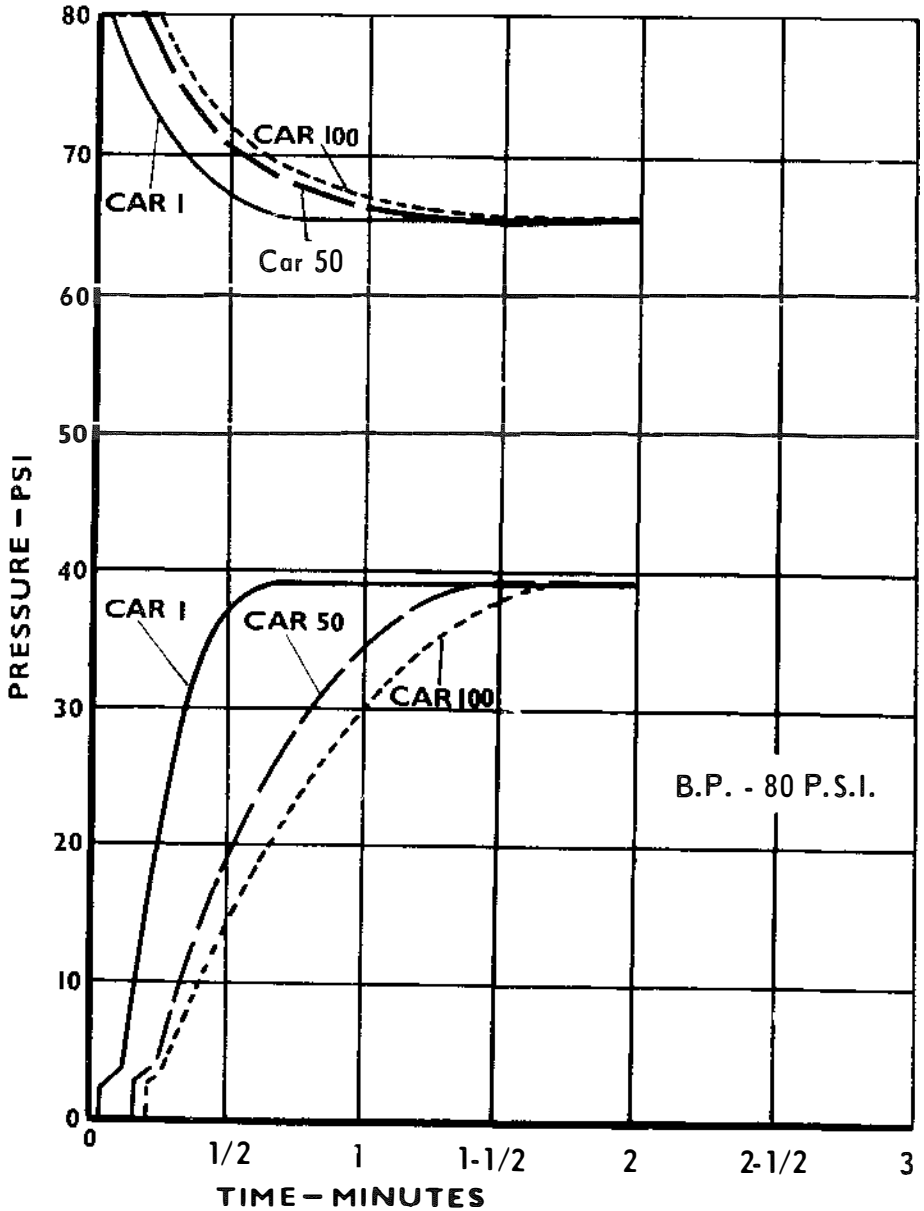


FIG. 76 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 15-PSI B.P. REDUCTION, 100-CAR TRAIN

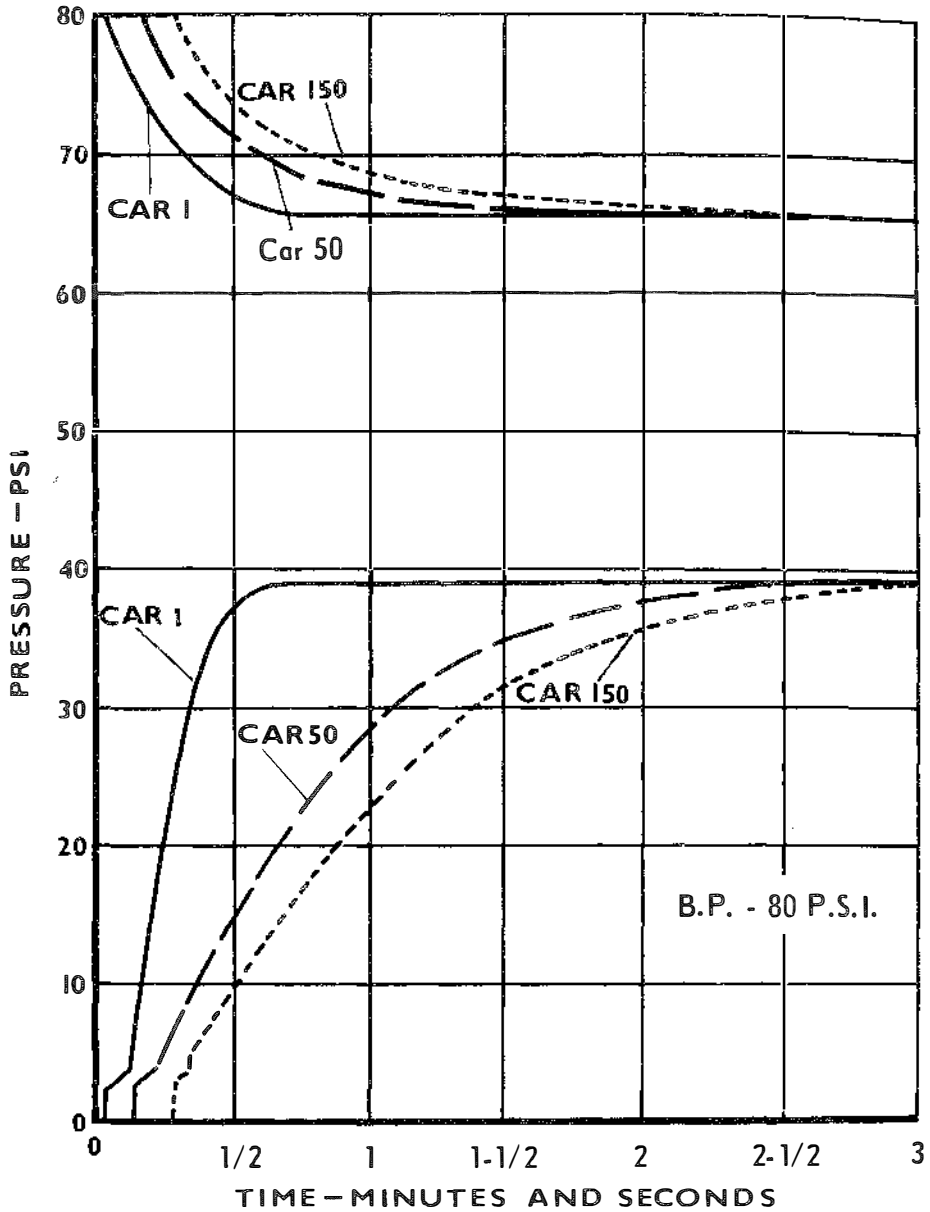


FIG. 77 BRAKE PIPE AND BRAKE CYLINDER PRESSURES DURING 15-PSI B.P. REDUCTION, 150-CAR TRAIN

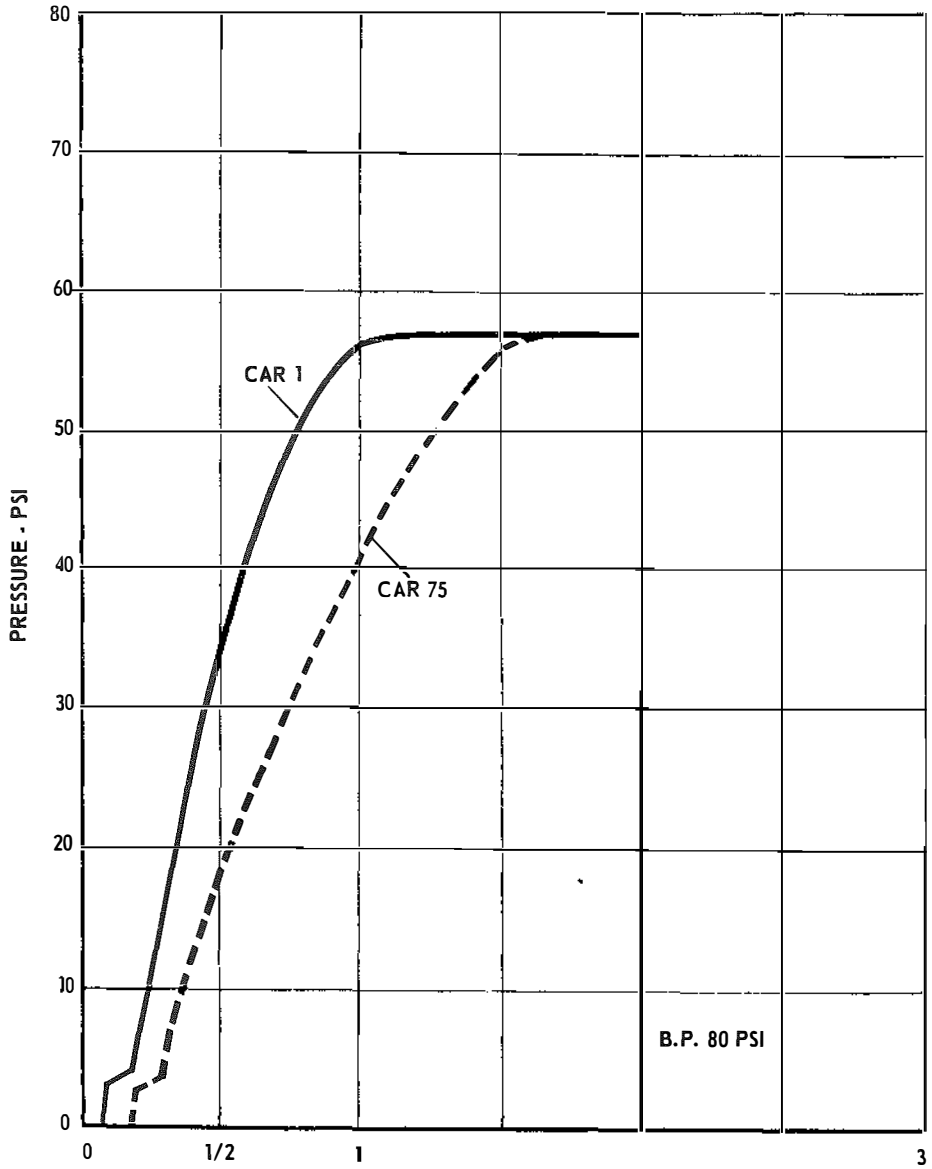


FIG. 78 BRAKE CYLINDER PRESSURE DEVELOPMENT FULL SERVICE APPLICATION—75-CAR TRAIN—50-FT BP/CAR

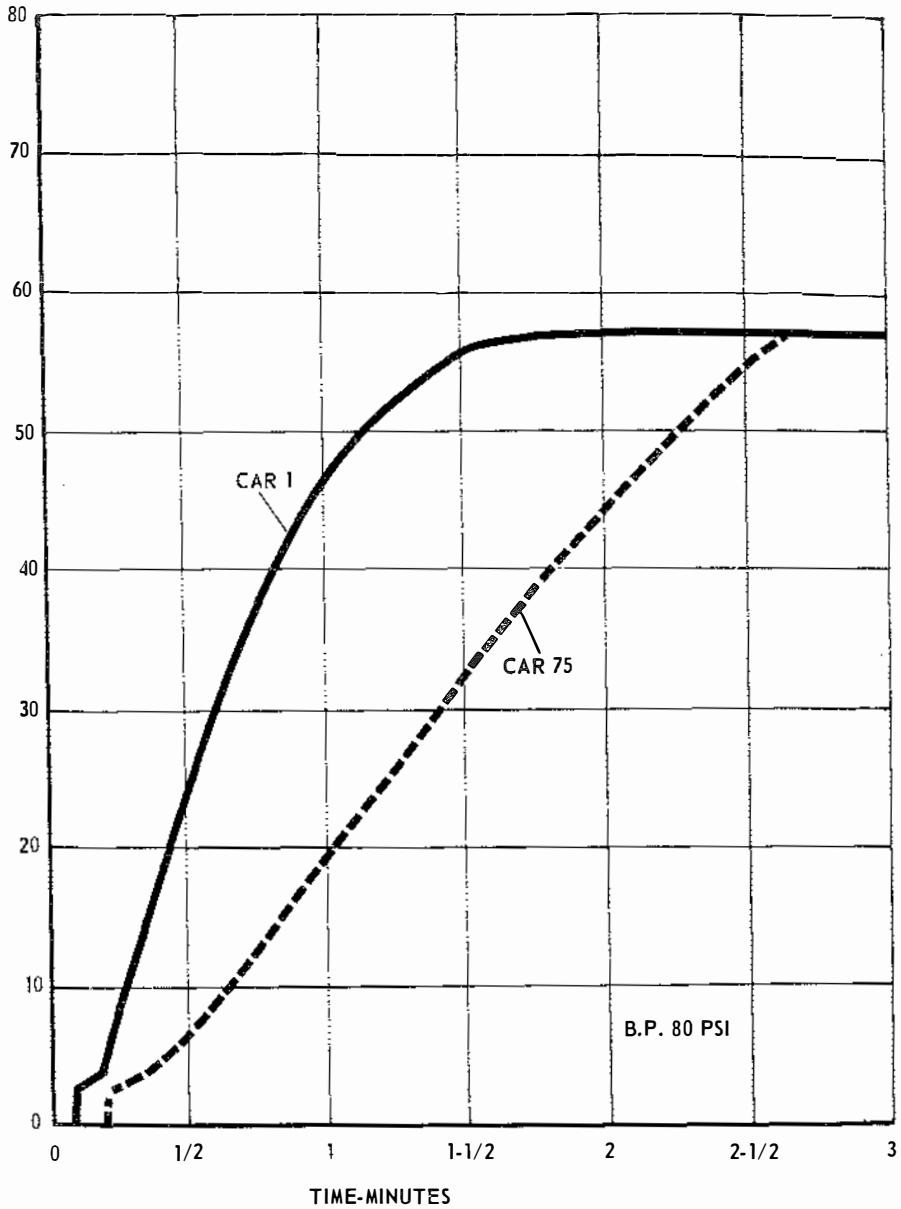


FIG. 79 BRAKE CYLINDER PRESSURE DEVELOPMENT
FULL SERVICE APPLICATION—75-CAR TRAIN—100-FT BP/CAR

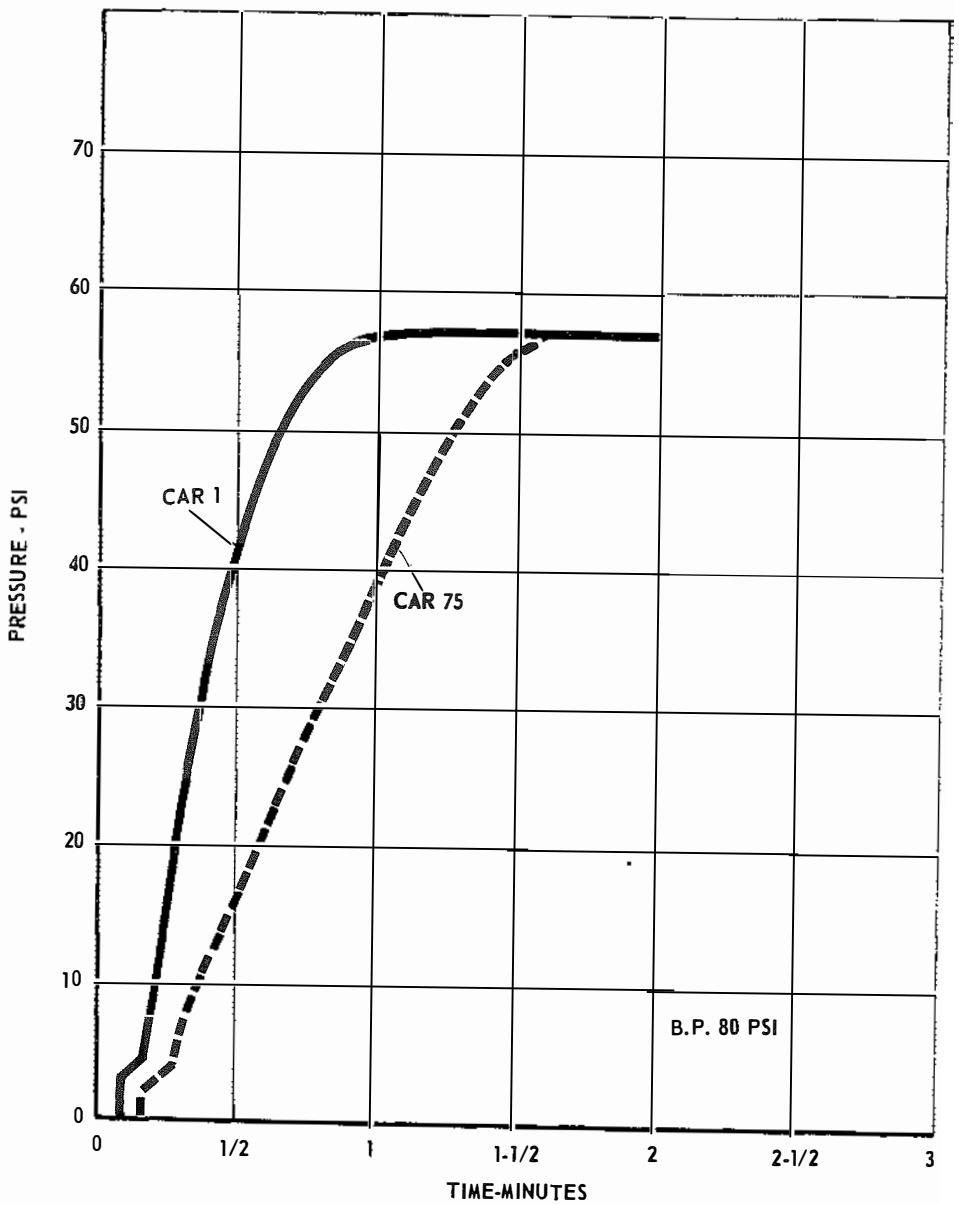


FIG. 80 BRAKE CYLINDER PRESSURE DEVELOPMENT
FULL SERVICE APPLICATION—75-CAR TRAIN—100-FT BP/CAR
WITH QUICK SERVICE VALVES

Gradient and Brake Pipe Leakage

The leakage condition existing in a train affects its performance. The effect of leakage on brake pipe pressure is dependent on the train length and the distribution of leakage within any given train length.

Brake pipe gradient is the difference in brake pipe pressure on the first car of a train and the last car of that train. True brake pipe gradient is the difference in pressures when the brake pipe is fully charged and false gradient is the difference in pressure when the brake pipe is not fully charged or is overcharged. True brake pipe gradient is caused by the following conditions: (1) amount of brake pipe leakage, (2) location of leakage, (3) feed valve setting, (4) train length, (5) amount of system leakage.

The curves on Fig. 81 show what effect the amount of leakage and location of leakage can have on train gradient. Fig. 82 is a plot of brake pipe gradient versus train length for three trains of 50, 100 and 150 cars, each having 5-psi/min. leakage and a 70-psi brake pipe.

When the leakage is evenly distributed through the train, the gradient in brake pipe pressure on the 50-car train is 3-psi. Doubling the length of the train to 100 cars results in 3 psi gradient. The train of 150 cars results in a 7-psi gradient.

When the leakage is concentrated in the rear third of the train, the same 5-psi/min. leakage results in larger gradients on the given train lengths.

Although the 50-car train is not affected a great deal, the 100-car train has increased to 6-psi gradient and the 150-car train to a 13-psi gradient. The gradient for the 100 and 150 car trains are approximately double those when the leakage was evenly distributed. Thus the amount of brake pipe gradient for any specific degree of brake pipe leakage depends upon the location of that leakage.

It should be noted that the effect of leakage at the rear of the train is of major importance to brake pipe gradient. Therefore, when checking trains for leakage, correction of leakage at the rear of the train will produce greater improvement in brake pipe gradient than correction of comparable leakage at the head end of the train.

The curves on Figure 82 demonstrate what effect increasing the feed valve setting has on gradient. These curves, which represent a 150-car train illustrate that as the feed valve setting increases the gradient also increases. For example: with a 70-psi feed valve setting and 3-psi/min. leakage, the gradient is 3 psi. If the feed valve setting is increased to 100-psi, the gradient increases to 6½-psi.

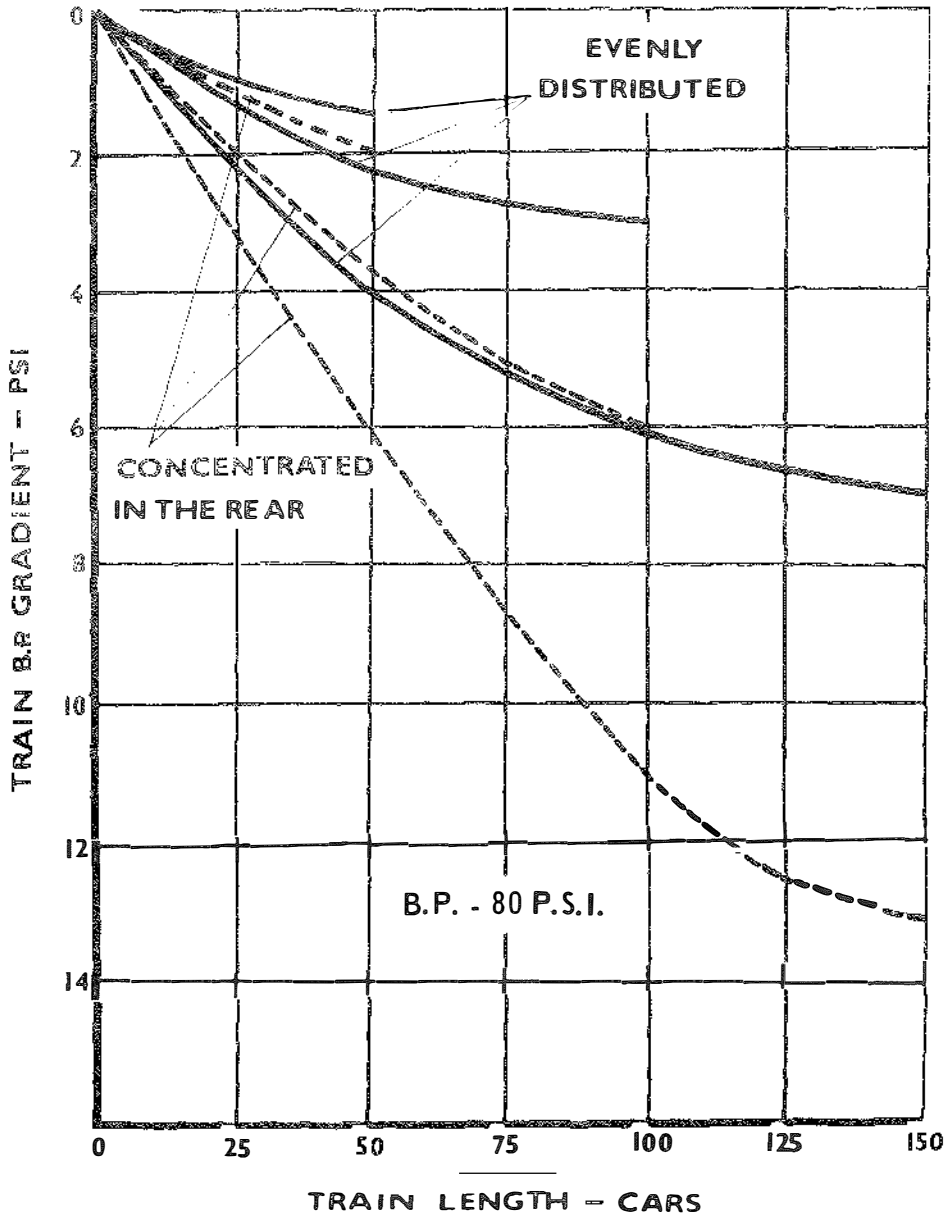


FIG. 81 TRAIN BRAKE PIPE GRADIENT FOR 5-PSI/MIN. BRAKE PIPE LEAKAGE

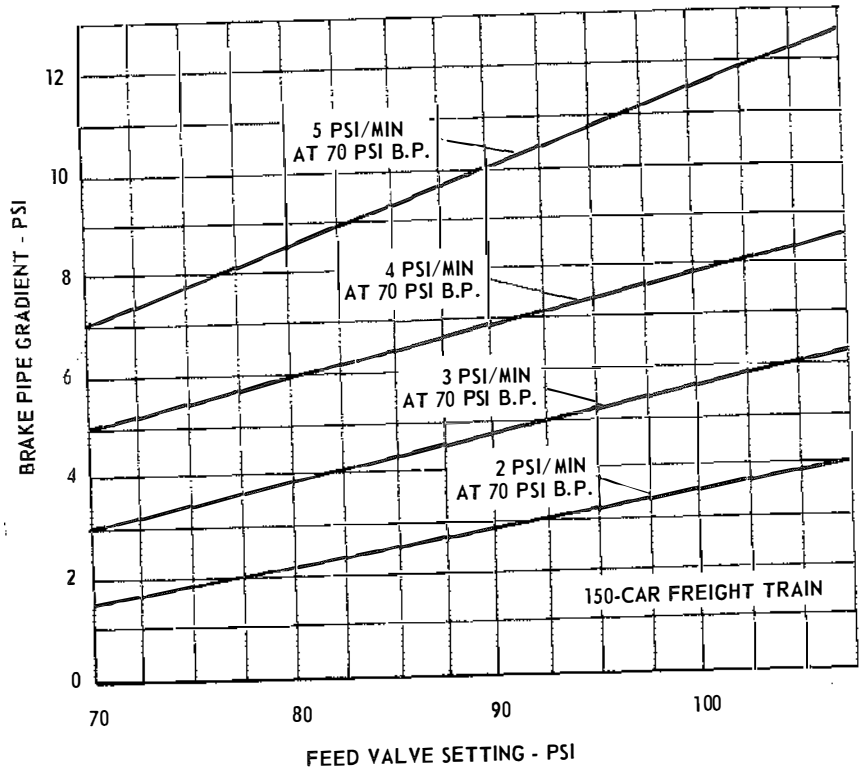


FIG. 82 EFFECT OF FEED VALVE SETTING ON BRAKE PIPE GRADIENT

The curves on Figure 83 show how increased train length affects gradient with various brake pipe leakages. These curves illustrate that as train length increases, gradient increases. For example: a 50-car train with 3 psi/min. leakage has a ½ psi gradient. If the train length is tripled, the gradient increases to 3¾ psi. It might also be noted that as leakage increases, gradient is affected to a greater degree. For example: 50-car train with 6-psi/min. leakage has a gradient of 1½ psi. If the train length is tripled, the gradient is increased to 12 psi. This curve is useful in predicting maximum rear car brake pipe pressures on trains.

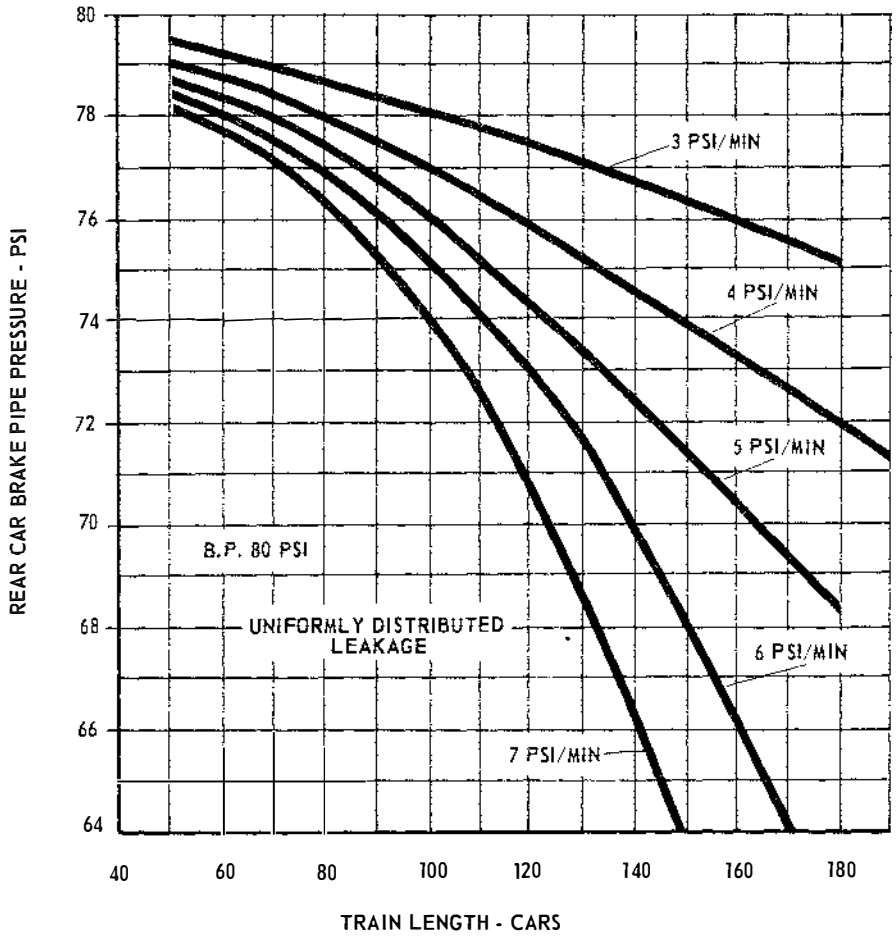


FIG. 83 MAXIMUM REAR CAR BRAKE PIPE PRESSURE WITH TRAINS OF VARIOUS LENGTHS AND LEAKAGES

SERVICE APPLICATIONS

Locomotive brake valves provide the means for the engineman to obtain any desired brake cylinder pressure on the train from a minimum pressure of 10 psi to equalization.

The brake pipe reduction time is dependent upon the train length and brake pipe leakage conditions. The volume of air that must be

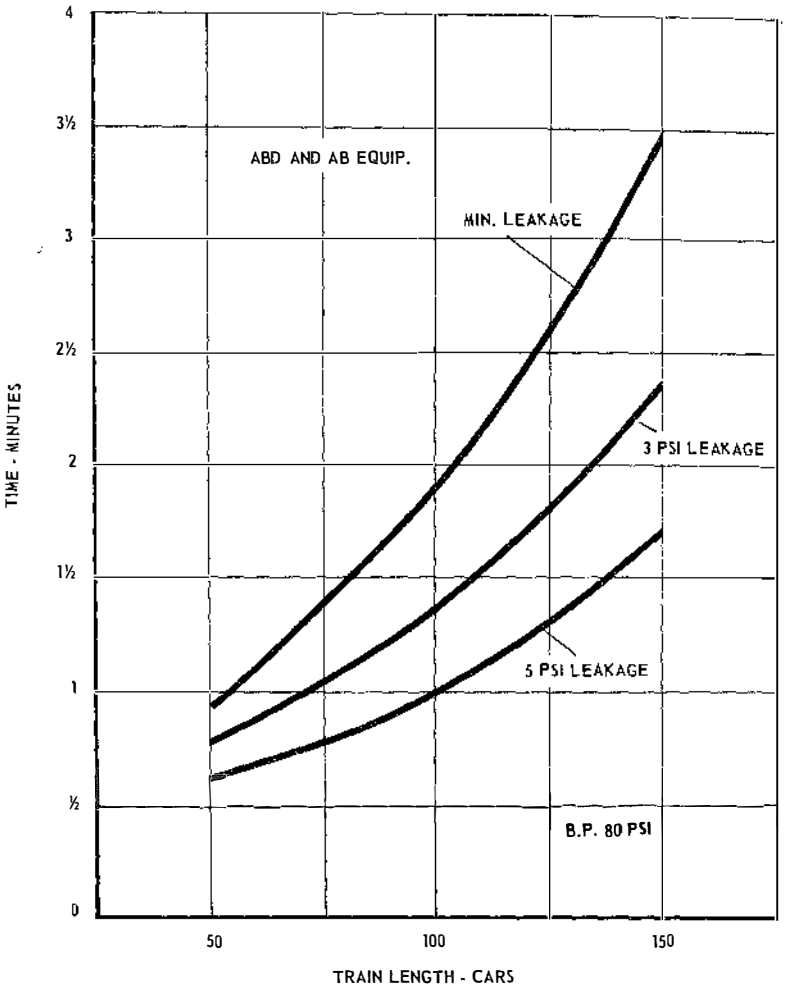


FIG. 84 BRAKE PIPE EXHAUST TIMES
VARIOUS TRAIN LENGTHS
20 PSI BRAKE PIPE REDUCTION

exhausted at the brake valve to reduce the pressure in the brake pipe a given amount is proportional to the total brake pipe volume. Thus, one could expect that the brake valve exhaust time on a 150-car train would be approximately three times that of a 50-car train of 1/3 the brake pipe length for the same degree of brake pipe reduction.

Brake pipe leakage has the effect of reducing brake valve exhaust times. A train having brake pipe leakage will reduce the volume of air required to be exhausted at the brake valve since during the reduction, a portion of the volume of air to be removed is exhausted at the leakage points along the length of the brake pipe.

Figure 84, relates the nominal brake pipe exhaust times for various train lengths and brake pipe leakage conditions for a 20 psi brake valve reduction. The train length is based on 50 ft. of brake pipe per car and the indicated times are for fully charged conditions to the brake pipe gradient for the leakage conditions.

One area of primary importance is that of minimum reductions. Modern locomotive equipment such as 26-L provides for a fixed minimum reduction. Previous equipments would permit almost any degree of brake pipe reduction under 6 or 7 psi. Thus, it is possible to make only sufficient reduction to initiate quick service activity in the train. Under this manipulation, the car equipment, by design, operates to locally vent brake pipe pressure to a measuring volume in the car control valve; and, on further movement of the control valve slide valve, the brake pipe pressure is permitted to flow along with auxiliary reservoir to the brake cylinder until nominally 10 psi brake cylinder pressure is developed. At this point, the flow of air from brake pipe to the brake cylinder is cut off.

Thus, there is the condition of reducing brake pipe locally at each car so that, taken independently, each car will produce a given amount of brake pipe reduction, depending upon the length of brake pipe and the cylinder volume. Hence, a car with short piston travel will produce less brake pipe drop due to quick service activity and, conversely, long piston travel will cause a larger brake pipe reduction for a given length of brake pipe on the car. Also, a car of shorter length brake pipe will produce a larger brake pipe reduction than will one of longer length for any given piston travel. These condtions can result in undesired brake release when maintaining brake valves, which do not have fixed amounts of brake pipe reduction for minimum brake applications, are employed.

Consider a 100-car train consisting of cars of various length from 50 to 85 feet being controlled by a maintaining brake valve of the DS-24M style. This style of brake valve will permit "super light" minimum brake applications to be made, if the first service position is not used.

A minimum brake application of 3½ to 4 psi equalizing reservoir reduction will cause quick service to be transmitted through the train. Those cars of shorter length will reduce brake pipe locally 5 to 6 psi; the longer cars will reduce brake pipe locally 4 to 5 psi. The brake pipe will

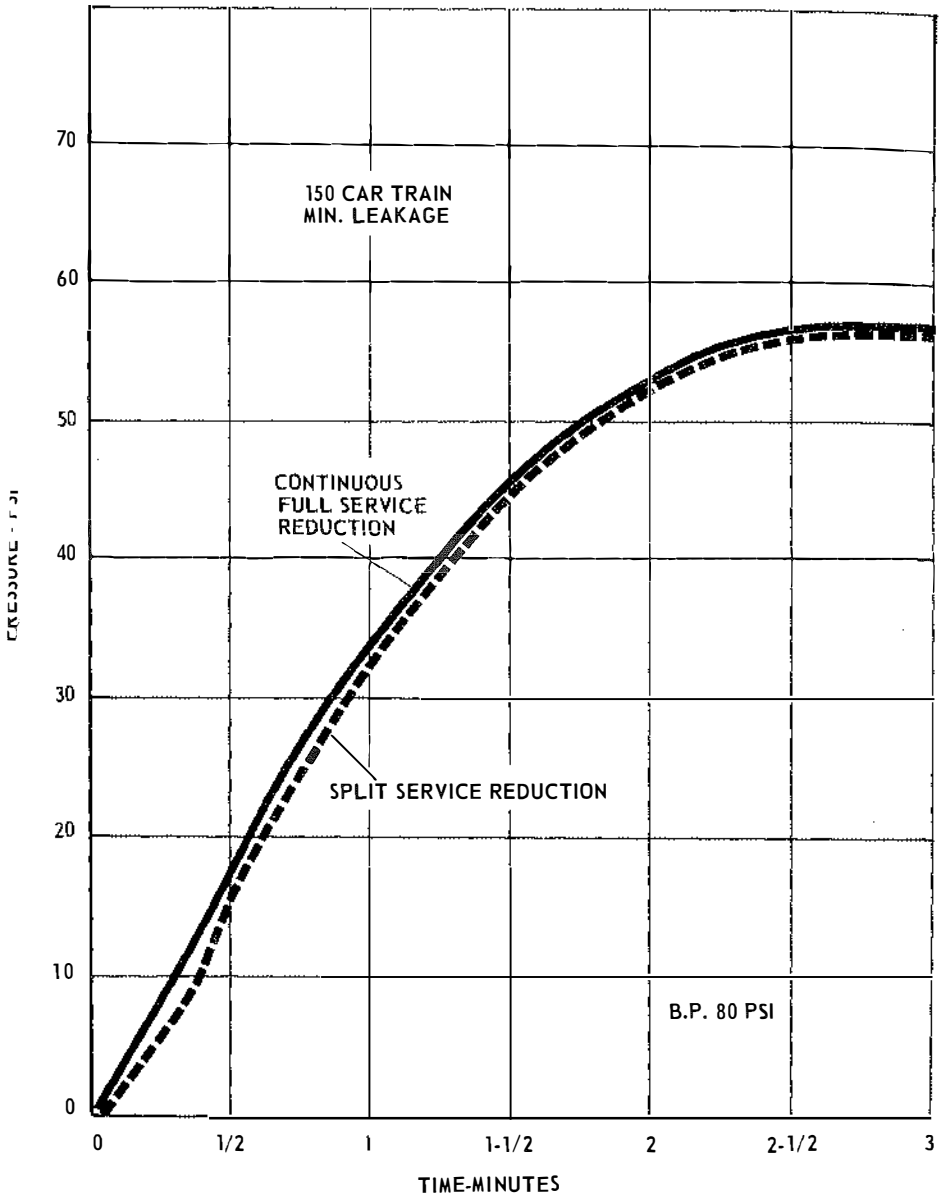


FIG. 85 TRAIN AVERAGE BRAKE CYLINDER PRESSURE DEVELOPMENT: STRAIGHTAWAY FULL SERVICE AND SPLIT SERVICE APPLICATIONS

ultimately equalize at a pressure throughout its length depending upon the proportion of long and short cars. Assume the equalized value was 5 psi below initial brake pipe pressure. The brake valve will maintain brake pipe pressure at 4 psi below its initial value. There now is the condition of the brake valve feeding air to brake pipe to bring its level from the 5 psi below initial brake pipe up to 4 psi below the initial brake pipe pressure. The increase in brake pipe pressure will cause those valves which made the heavier local quick service brake pipe reduction to go to release. When a brake valve release is attempted, the brake pipe pressure at the rear of the train will rise very slowly. If AB control valves on cars toward the rear of the train have service piston ring leakage of 3 psi/min., it is very possible that the valves, if they have not already released because of maintaining, will not release at all, resulting in "stuck brakes". This occurs because the auxiliary reservoir pressure behind the piston is charging, by way of piston ring leakage, at about the same rate as brake pipe is charging; and no differential is obtained to cause the piston to go to release.

"Super light" minimum reductions should be avoided to prevent "kickoff" of brakes and eliminate stuck brakes. Minimum initial brake pipe reductions should be between 5 to 7 psi. Release of a minimum reduction is conducive to stuck brakes; where possible, an additional reduction should be made so that the release is made from a 9 to 10 psi brake pipe reduction to avoid the possibility of "stuck brakes".

The use of a split service reduction or graduated application is widely used for applying train brakes. This type of application is made by making a 6 to 7 psi initial reduction, waiting for approximately 20 seconds, then continuing the reduction to the desired brake pipe pressure.

This results in having quick service run through the train and assures a minimum brake cylinder pressure on all cars of 10 psi. The 20-second delay allows the brake shoes to go against the wheels, providing light retarding force to the train and snubbing slack action. Additional braking effort is then started, after the train slack has been controlled, to the degree required to control the train. The use of a split full service reduction as compared to a continuous reduction from 80 psi brake pipe pressure is shown on Figure 85. As can be seen, only a very slight difference in average train brake cylinder pressure exists at any instant of time until full pressure is obtained even though a delay of 20 seconds occurred from the time the initial reduction was made and the second application was started on the split reduction.

A common practice when stopping trains is to use a split full service application by making the initial brake pipe reduction of 6 to 7 psi, waiting approximately 20 seconds, then continuing the reduction to that required to control the train. When the train is within 75 to 100 feet of the stopping point, make a further service reduction so as to assure brake pipe exhaust is open when the train comes to rest. This has the

advantage that, as the train comes to a stop, the slack will gather and starting of the train following the stop is made easier.

The full service reduction should be fully understood. A 20 psi brake pipe reduction will produce 50 psi brake cylinder pressure on cars having 10-in. cylinders at nominally 8 in. brake cylinder piston travel or 12-in. cylinders with nominally 5 in. piston travel when the initial brake pipe pressure is 70 psi. This also represents equalization, that condition when the car auxiliary reservoir pressure and the brake cylinder pressure are equal in value. Any additional brake pipe reduction will not result in an increase in brake cylinder pressure. A 20 psi brake pipe reduction will result in 50 psi brake cylinder pressure from any brake pipe pressure in excess of 70 psi, but will not produce equalization. The amount of reduction required to produce full service equalization and the brake cylinder equalization pressure for various brake pipe pressures are shown in Table 1.

TABLE 1.

Brake Pipe Pressure, psi	Brake Pipe Reduction for Equalization, psi	Service Brake Cylinder Equalization Pressure, psi
110	32	78
100	29	71
90	26	64
85	25	60
80	23	57
75	22	53
70	20	50

Service Release—The release of service applications is initiated by movement of the brake valve handle to release position or "running." This causes the brake valve to restore air pressure to the brake pipe. The increasing brake pipe pressure then causes the car equipments to move to release, exhausting brake cylinder pressure through the retainer and recharging the reservoirs.

The time to initiate the release of the brakes on the last car in a train is dependent upon several factors:

a) Train length
b) Brake pipe leakage
c) Amount of brake pipe pressure being restored
d) Type of car equipment—AB or ABD

In general, the time required to achieve release of the brakes on the last car of a train is longer as train length increases. The release time becomes longer as train brake pipe leakage increases regardless of train length. The release time increases with light reductions. Over reductions likewise, require longer release times. The degree of increase is most noticeable on the minimum reductions because the pressure head to restore brake pipe pressure is low and results in longer times to achieve release. The type of brake equipment alters the release time. Since the ABD control valves incorporate a service accelerated release feature, this will cause release times to be shorter than that obtainable with the AB control valves.

Curves, Fig. 86, and 87 shows nominal release times for three degrees of reduction as a function of train length for the conditions of minimum and 5 psi/min. leakage.

For brake applications of equalization or less, it is necessary that brake pipe pressure increase only about 1½ psi at each car location to cause the valve on that car to move to release. If an overreduction has been made, that is, brake pipe pressure reduced below that required to produce equalization, a release of the brakes on any car cannot be accomplished until brake pipe pressure has been increased to the equalization pressure plus the 1½ psi. This is of importance particularly with long trains where the time to obtain release is materially lengthened by an overreduction.

Wherever possible, the release of light brake pipe reductions should be avoided by increasing the amount of reduction before initiating the release. This procedure will avoid stuck brakes and is particularly useful on trains of 150 cars and longer or trains which have maximum permissible brake pipe gradients.

When making running releases of service applications, it is important to allow sufficient time for the release of the brakes through the train before applying power. The times tabulated previously should provide a guide. Each train with its own characteristics of brake pipe leakage, length, and degree of reduction will govern the situation. Applying too much power too soon after initiating the release can result in a break-in-two if slack conditions are not right.

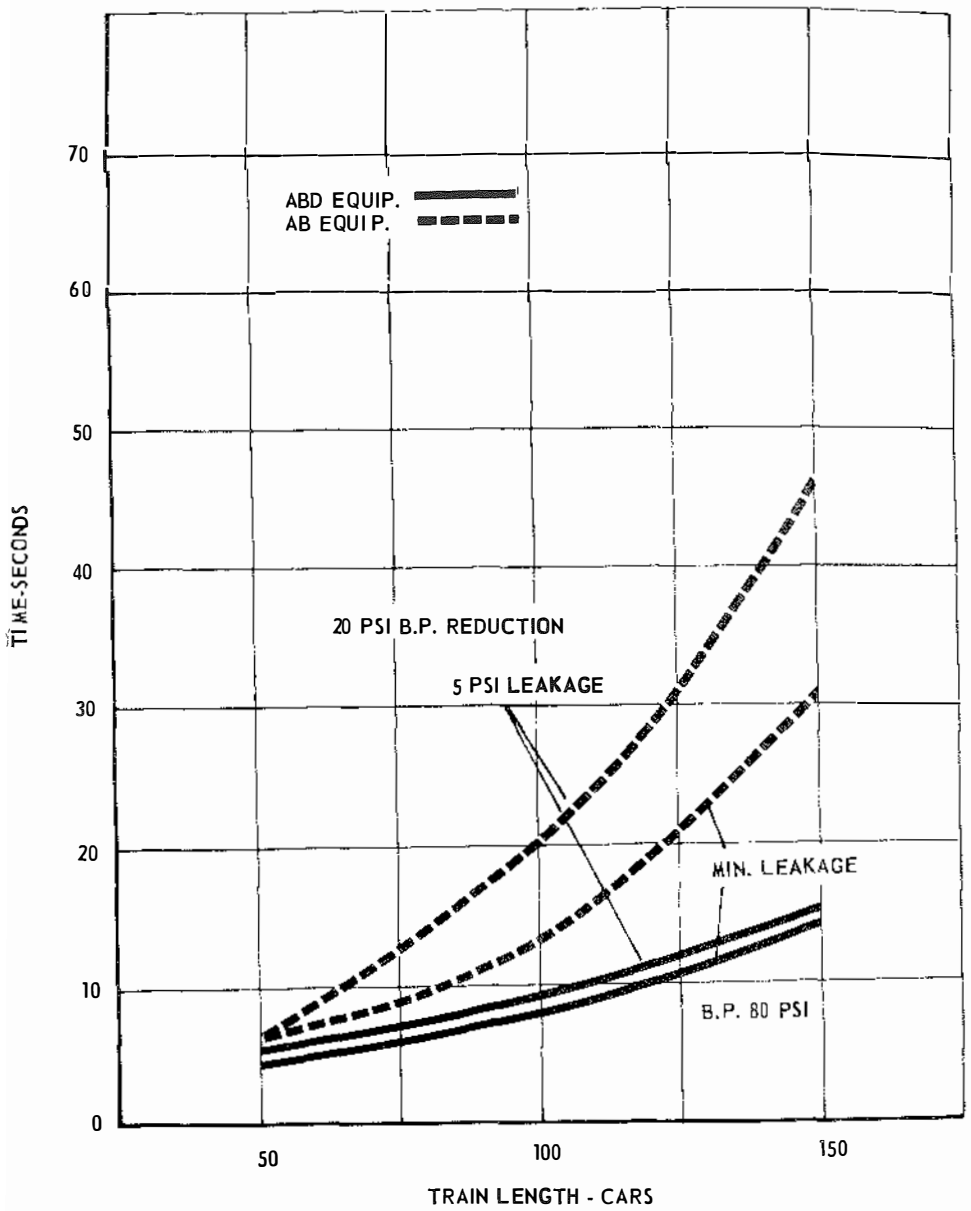


FIG. 86 TIME TO START BRAKE RELEASE OF 20 PSI ON REAR CAR

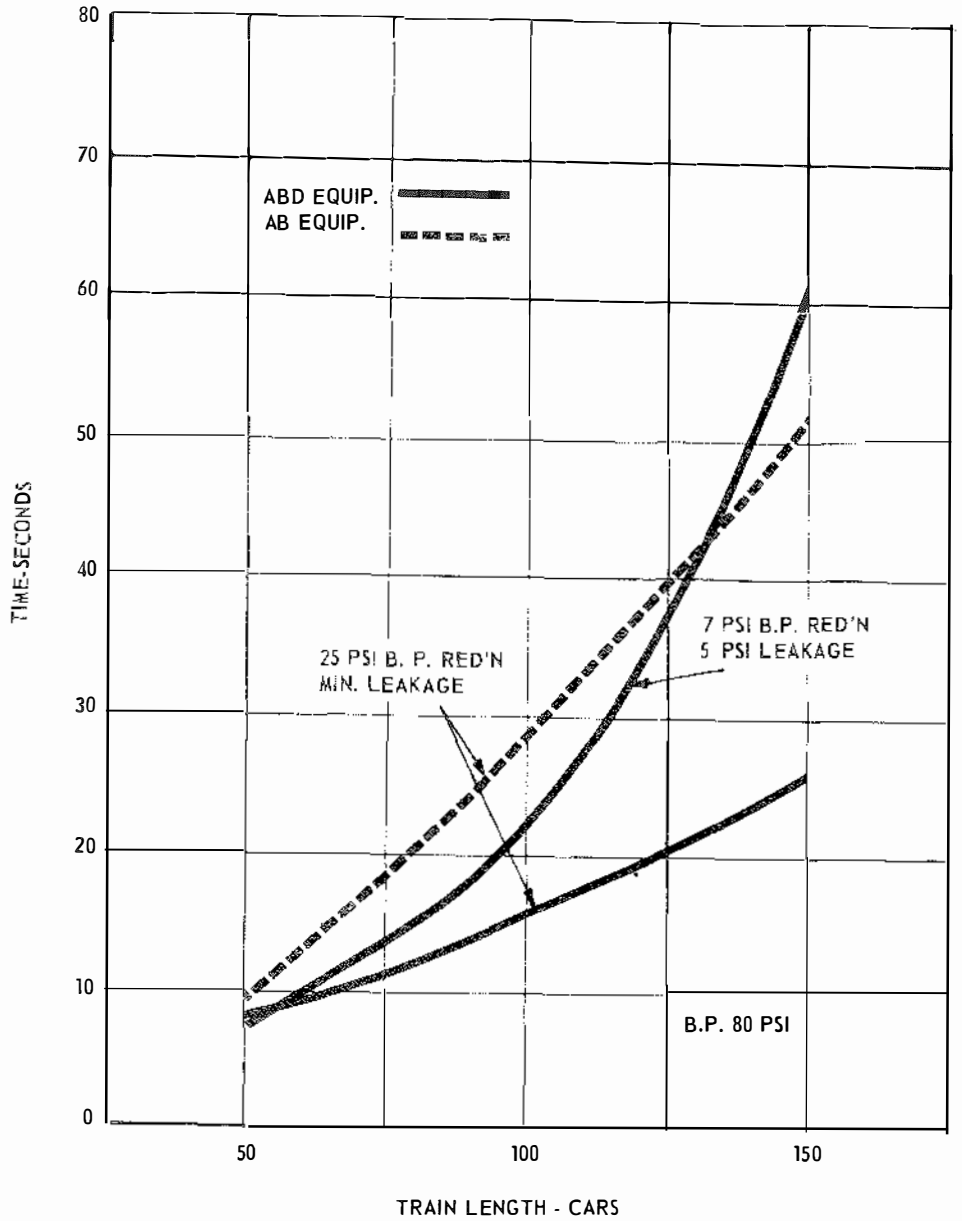


FIG. 87 TIME TO START RELEASE ON REAR CAR
7 AND 25 PSI REDUCTIONS
MIN. AND 5 PSI REDUCTIONS

INDEPENDENT BRAKE

The independent brake permits applying braking force to the locomotive or locomotive consist independent of the train brakes. Probably no element of braking can create train shock conditions more severe than improper use of the independent brake.

The independent brake may be used to good advantage during slow downs and stops; however, it must be handled with care. Applications should be made by slowly applying the independent brake under any circumstance, if train shocks are to be avoided. Similarly, the release of the independent brake should be made slowly to avoid severe runouts, particularly when train slack has been bunched. The following tabulation provides nominal times for application and release and actuating pipe charging exhaust on a four unit and six unit consist using an S-40-D and SA 26 independent brake valves having 70 ft. of pipe per unit, 50 psi maximum full independent setting, and 130 psi main reservoir pressure.

TABLE 2

Independent Application and Release Pipe

	Four-Unit Consist		Six-Unit Consist	
	Appl. 0-45 psi	Rel. 50-5 psi	Appl. 0-45 psi	Rel. 50-5 psi
	Time-Sec.	Time-Sec.	Time-Sec.	Time-Sec.
SA-26	3.9	6.6	7.6	11.5
S-40-D	5.4	10.0	9.7	17.0

Actuating Pipe—#13 Pipe

	Four-Unit Consist		Six-Unit Consist	
	Appl. 0-30 psi	Rel. 130-10 psi	Appl. 0-30 psi	Rel. 130-10 psi
	Time-Sec.	Time-Sec.	Time-Sec.	Time-Sec.
SA-26	2.0	11.3	3.3	18.7
S-40-D	2.4	8.8	4.2	14.6

Variations should be expected from the above depending on piping configurations, pipe volume changes, and pipe lengths.

The independent brake valve on the lead unit of the consist should always be left in the application position when there is no attendant in the cab.

EMERGENCY APPLICATION AND RELEASE

The emergency application of freight brake equipment provides an extremely rapid transmission of the application throughout the train, as well as developing higher brake cylinder pressure than is obtained during service braking.

By movement of the brake valve on the locomotive to emergency position, the brake pipe is vented unrestricted to atmosphere. This rapid drop in brake pipe pressure acts on the emergency portion of each succeeding valve to cause it to go to emergency and vent brake pipe pressure to atmosphere at that location. This serial action of transmission results in an ability to transmit an emergency at the rate of 930 feet per second or 635 miles per hour. The action of emergency is such that the AB or ABD control valves will apply rapidly causing approximately 15 psi brake cylinder pressure to occur on each car within 1½ seconds after that car has gone to emergency position. This action applies the brake shoes to the wheel quickly and minimizes severe slack changes. Each car operates to increase pressure at a controlled rate until full emergency pressure is obtained.

Since the auxiliary and emergency reservoirs are changed from the brake pipe, the equalized emergency brake cylinder pressure is basically a function of the brake pipe pressure and is nominally 60 psi when 70 psi brake pipe pressure is employed. The resulting brake cylinder pressure will be higher from brake pipe pressures over 70 psi and lower from brake pipe pressures less than 70 psi. Table 3 shows the emergency brake cylinder pressures obtained from various brake pipe pressures where equipment is fully charged.

TABLE 3.

Brake Pipe Pressure, psi	Emergency Brake Cylinder Pressure, psi
110	93
100	85
90	77
85	73
80	69
75	65
70	60

Emergency applications when made on a train should never be released until the train has come to a stop. The car brake equipment will not permit a release until one minute has elapsed, and any attempt to do so results only in wasting air.

An emergency application which occurs from the caboose or within the train will be recognized at the locomotive. The engineman should immediately place the automatic brake valve in a position to cut-off brake pipe charging and reduce throttle to idle.

The release of an emergency application requires time. Even though car equipments can be release in 3½ to 4 minutes on a 150-car train, 20 to 30 minutes may be required to recharge the car reservoirs on the rear of the train to within 5 psi of their initial condition.

Damaging slack actions which could occur during emergency application with older car brake equipment has been reduced to a minimum with present day equipment.

INCREASING OR DECREASING TRAIN BRAKE PIPE PRESSURE AND DISSIPATING AN OVERCHARGE

When changing train brake pipe pressure, certain precautions should be observed to avoid stuck brakes or unintentional release of brakes.

Increasing brake pipe pressure from a lower pressure to a higher pressure is readily accomplished by resetting the feed valve to the higher desired pressure. This should be done only when a release of brakes is to be made or when brakes are released. No attempt at increasing brake pipe pressure should be made while a brake application is desired since the increasing pressure will cause release of the brakes. However, if the new feed valve setting produces a brake pipe pressure higher than is desired, *no* attempt to decrease the setting should be made without, first, making a service brake application of the train brakes. To do otherwise will result in stuck brakes. Also sufficient time should be permitted for equipments to recharge to the new pressure.

There are several methods of reducing the overcharged condition of reservoirs on trains. One good method for reducing this overcharge on fully charged trains is to:

1. Adjust the feed valve for the desired brake pipe pressure.
2. Place the automatic brake valve handle in emergency position for one (1) minute.
3. Place the brake valve handle in running position until the brake pipe gage shows twenty psi pressure.
4. Place No. 24-RL Automatic Brake Valve handle in lap position (No. 26-C Automatic Brake Valve handle in handle-off position) and permit service exhaust of brake pipe air for one (1) minute.
5. Place the automatic brake valve handle in release position and charge the train in preparation for the air brake test.

If the train is not fully charged, it will be necessary to place the brake valve handle in running position for three (3) minutes prior to Step 1. In order for this method to reduce the overcharge, the accelerated emergency release function must occur. It can only occur if there is air in the auxiliary reservoir. This is why the brake pipe is charged for three (3) minutes.

Another method for reducing a brake pipe overcharge is:

Make an emergency application, release with the feed valve set ten psi below the original setting. When the brake cylinder on the last car has *fully released,* make a second emergency application. Set the feed valve to twenty psi below the original setting and release.

In general, it may be said that an emergency from a given brake pipe pressure will safely reduce reservoir pressures so that a release can be accomplished from a brake pipe pressure 10 psi below the initial pressure. Although other manipulations may accomplish the same purpose, the procedure outlined will assure that all reservoirs are adequately reduced to avoid any subsequent failure of brakes to release or then possible reapplication.

The procedure above can be used with train makeups of solid ABD Equipment; however, because accelerated service release is available on this equipment, it is possible to accomplish the reduction of emergency reservoir pressure through this function. For example, if a train consisting of 100% ABD Brake Equipment is to be changed from 90 psi brake pipe pressure to 70 psi, the following procedure is suggested.

Make a 25 psi service reduction from the 90 psi brake pipe condition: reset the feed valve to 80 psi and release. When the last car cylinder has *fully released,* make a 25 psi reduction. Reset the feed valve to 70 psi and release.

The ability to obtain accelerated service release makes the time required to accomplish the change in brake pipe pressure materially shorter than with AB Equipment. However, as stated above, this procedure must only be used when the train consists entirely of ABD equipped cars.

THE BRAKE PIPE FLOW INDICATOR

The brake pipe flow indicator, Fig. 89, is an instrument which indicates the rate of flow of air through the automatic brake valve to the brake pipe. It may be used with any of the brake equipment presently in use.

This instrument is actually a differential pressure gage which indicates on its dial a difference between two pressures. It also actuates a switch which lights a lamp as an added indication. The lamp switch may be set to light the indicating lamp at any desired reading.

The brake pipe flow indicator is the only indicator which the engineman has which will inform him as to what is taking place in the brake pipe in regard to air flow. In locomotive brake equipment, such as the No. 6 types and the 24-RL, the flow indicator has one of its connections piped to the feed valve pipe and the other connection piped to the brake pipe. In the 26-L equipment, these connections are made across a check valve

and choke arrangement known as the A-19 flow indicator adapter, which is placed in the main reservoir pipe to the 26-C brake valve. With the No. 6 and 24-RL types of locomotive brake equipment, the flow indicator indicates the difference in pressure between the feed valve pipe or core and the brake pipe—the greater the differential, the greater the air flow. With 26-L Equipment the flow indicator indicates the difference in pressure across the choke orifice in the A-19 flow indicator adapter, Fig. 89, and, here also, the greater the difference, the greater the air flow.

The brake pipe flow indicator, because it indicates the rate of flow of air to the brake pipe, may be used to indicate several things.

It can indicate when a train is charged. It can indicate when excessive leakage is present. The indicated reading is not an actual measure of brake pipe leakage, but represents the condition of air flow into the brake pipe. It can indicate when the brakes are being applied from the caboose, an occurrence which does not show on the locomotive brake pipe gage.

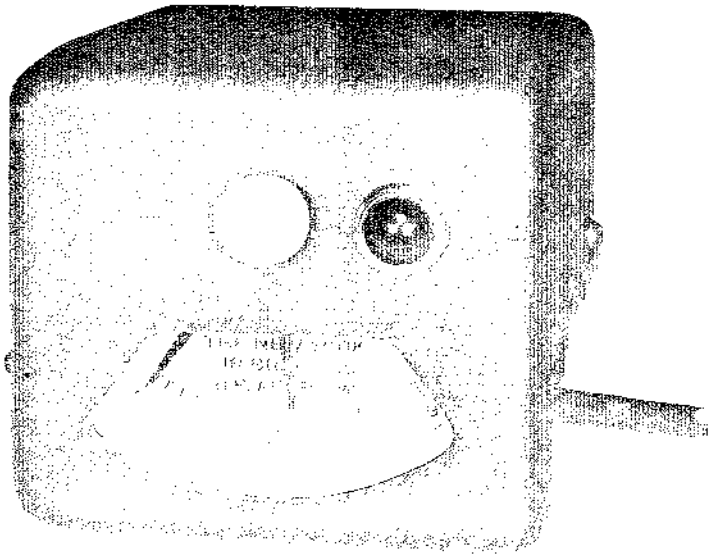
In cold weather, the flow indicator can be of assistance, as it can indicate whether difficulty in obtaining sufficient pressure on the rear or caboose is due to leakage, possible freeze-up, restriction in the locomotive brake pipe, or the first few cars of the train.

Referring to the illustration showing the brake pipe flow indicator, it will be noted that there are two pointers. One of these is colored black, and this pointer indicates the brake pipe air flow. The other pointer is colored red and may be set at any point; for example, it might be desirable to indicate a minimum flow at a certain time. To adjust the red hand, the adjusting knob in the center of the cover above the dial is turned. The indicator lamp is shown to the right of the adjusting knob. This lamp shows amber through the lens.

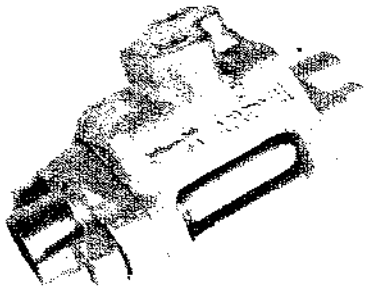
SAFETY CONTROL

The function of the safety control system is to ensure control of a moving train should physical impairment or inattention of the engineman actuate the system. It does this by requiring proper attention or an intermittent action by the engineman. Should distraction or physical impairment interrupt the normal supervisory function of the engineman, the brakes will apply and stop the train. There are several types of safety control devices in use today, such as:

1. *Pneumatic Foot Valve*—This arrangement requires that a foot valve be continuously depressed while operating the locomotive. If the engineman releases the foot pedal, a warning whistle in the cab begins to sound and continues to sound for the interval provided in the time delay feature, generally 4 to 6 seconds. If the



TYPE B BRAKE PIPE FLOW INDICATOR



BRAKE PIPE FLOW INDICATOR ADAPTER
FIG. 89

warning whistle is ignored, a safety control brake application will automatically be initiated and engine speed will be reduced to idle. To prevent a penalty brake application in the time delay allowed, the foot pedal must be depressed or a manual brake application of approximately 25 psi brake cylinder pressure must be made.

2. *A cycling device* can be incorporated with the foot pedal system which requires that the engineman depress and release the foot valve at specific intervals rather than hold the foot pedal continuously depressed. After the engineman has held the foot pedal depressed for a specific time, the safety control whistle will begin to sound. If the engineman fails to depress or release the foot pedal within the specified time after the whistle begins to blow, a service rate brake application will automatically be initiated and the engine speed will be reduced to idle.

3. *Electronic Alertness Control*—The engineman's seat is equipped with a built-in antenna. This is essentially a copper screen which is suitably protected against physical damage by a ventilated, elastomeric coating. It is located directly beneath the seat upholstery. As the engineman goes about his normal activity, such as adjusting throttle position or applying brakes, sanding, blowing horn, etc., these motions produce a detectable change in the energy output of the seat antenna. Any such changes reset the control and start a timing circuit. If, during the timing period (normally 20 seconds), no additional motion is detected, an audible and/or visual signal is provided to call his attention to this fact. If motion is still not present for an additional nominally ten seconds, a relay contact is opened; and this signal is used to apply brakes and reduce engine speed to idle.

To release the brakes and regain power, with any of these systems, the automatic brake valve handle must be placed in suppression, lap, (depending upon the type of brake equipment on the locomotive) or emergency position until the brake application valve resets and the throttle is returned to idle.

AUTOMATIC TRAIN STOP AND AUTOMATIC TRAIN CONTROL SYSTEMS

1. Classification of Equipment
   There are several types of equipment in use which may be classified in accordance with the kind of information or protection provided as follows:
   a. Cab Signal System: This system provides for the display of signal indications in the cab, and a warning whistle which sounds following the signal changes to a more restrictive indication until the engineman operates an acknowledging device.

   b. Automatic Stop System (Continuous): This system provides for the display of signal indications in the cab with a warning whistle and an automatic brake application following the signal change. The automatic brake application may be forestalled, provided the engineer acknowledges the signal change within a fixed time.
   c. Speed Control System: This system provides for the display of signal indications in the cab and automatic brake applying apparatus to enforce speed restrictions in accordance with signal indications. A warning whistle sounds when the prescribed speed limit is exceeded or when an acknowledgment of a signal change is required. The *automatic* brake application may be suppressed if the engineman makes a manual service brake application within a fixed time after the whistle sounds and holds this application until the speed is reduced below the prescribed limit. An acknowledgment of the signal change to a more restrictive indication is required to forestall the automatic brake application even though the speed is below the prescribed speed limit.
   d. Intermittent Inductive Automatic Stop System: This system is basically different from the three systems described previously in that the control is intermittent instead of continuous, i.e., the control of the locomotive equipment is obtained from track elements located at signals or at other points along the right-of-way. This system provides for an automatic brake application at approach or restrictive wayside signals. This brake application may be forestalled if the engineman operates an acknowledging device at the signal location. Signal indications are not displayed in the cab with this system.
2. The equipments are further classified in accordance with type of track circuit control for the cab signal as follows:
   a. Two Indication Non-Code System: In this system, two signal indications are provided. A clear indication is obtained with an a.c. current superimposed on the regular track circuit in the running rails, and a restricted indication is obtained from this when current is removed.
   b. Three Indication Non-Code System: This system provides for the display of three signal indications in the cab. The control is obtained from two a.c. circuits in the running rails.
   One of these is the track or axle circuit in which current flows from a transformer at the leaving end of the block through the other rail. In the second, known as the loop circuit, current flows from a transformer at one end of the block through the two rails in multiple and returns through a line wire. A clear indication is obtained with these two circuits energized with current of a prede-

termined relative polarity. An approach indication is obtained with the polarity of one of these circuits reversed. A restricting indication is obtained with one or both of these circuits de-energized.

c. Code System: In this system, two, three or four signal indications may be obtained. The control is obtained from an a.c. current in the running rails which is interrupted or coded at a fixed frequency for a given signal indication. A clear indication is obtained with a code frequency of 120 cycles per minute; an approach indication with a code frequency of 75 cycles per minute; and a restricting indication with non-coded or no current in the rails.

3. Apparatus Used With Each System

a. Cab Signal System: The essential apparatus used with the Cab Signal System comprises the following:

1. Track Receiver: This may be a one or two-piece type and is mounted ahead of the front truck wheels. For locomotives equipped for reverse running, a second receiver is mounted at the rear of the locomotive.
2. Loop Receiver: This receiver is used only with the Three Indication Non-Code System and is mounted at or near the rear of the locomotive.
3. Equipment Box: This box houses control apparatus such as the amplifier, relays, decoding units, dynamotor, etc.
4. Cab Signal: This signal is designed to display signal aspect as standardized by the railroad company.
5. Acknowledging Switch: This is a manually operated device and is used by the engineman to acknowledge a change to a more restrictive signal indication.
6. Whistle Magnet Valve: This is an electro-pneumatic device used for the control of the warning whistle.
7. Motor Generator Set or Static Power Converter: This unit is used on diesel locomotives to supply power to the cab signal equipment at 32 volts from the 64 volt locomotive battery.

b. Automatic Stop System: This system requires all of the apparatus used with the Cab Signal System and, in addition, the following:

1. Timing Valve, Magnet, and Reservoir: This is an electro-pneumatic device used in place of the whistle magnet valve and functions to provide the whistle, the delay time, and the control of the brake application valve.
2. Brake Application Valve: This device controls the automatic brake application.

c. Speed Control System: This system requires all of the apparatus used with the automatic stop system and, in addition, the following:

1. Speed Governor: This is a centrifugal or electronic type governor mounted on a journal box and driven from the end of the

axle. It is equipped for the control of one, two, or three speed limits.
2. Suppression Valve Group: This is a group of valves designed to function with the brake applying apparatus to permit the automatic brake application to be suppressed with a manual service brake application.

d. Intermittent Inductive Automatic Stop System: The essential apparatus used with this system includes the following:

1. Receiver: This is mounted on an unsprung portion of the locomotive on the right-hand side, usually on a journal box. It is a core and coil assembly similar in structure to the inductor mounted on the track. The control functions are transmitted from the track to the locomotive equipment as the engine carried receiver passes over the track inductor.
2. Relay Box: This houses a relay which is controlled by the receiver.
3. Magnet Valve: This is controlled by the relay and through its valve structure controls the brake application valve.
4. Brake Application Valve: This device controls the automatic brake application.
5. Acknowledging Valve: This is a manually operated device used by the engineman to forestall an automatic brake application.
6. Reset Cock: This is sometimes used to reset the brake application valve. A stop reservoir and pneumatic circuit controller may be used in place of the reset cock to provide a time element reset.

AIR AND DYNAMIC BRAKE

Because the dynamic brake concentrates the braking force and braking horsepower at the head end of the train, there are practical limits concerning the amount of braking that can be done with the dynamic brake alone. The ideal situation is to have all locomotive units and the train do their share of braking. However, the division of the braking work done by the cars and the locomotive units equipped with dynamic brake is important to obtain the best train operation in any particular situation. In practical terms, it has been found that from 200,000 to 250,000 lb. of retarding force concentrated on the locomotive is the most that should be used when going through turnouts, into and out of passing tracks and on sharp curves. A large consist of modern diesel engine units has the capability of producing considerably more than 250,000 lb. of retarding force with the dynamic brake. Caution must be exercised in the amount of dynamic brake which is to be used not only for grade braking operations, but also for assisting in slowdowns and stops.

When unloaded long-overhang, or long high cars are located near the locomotive consist, the above limits may be too high. During operation at high dynamic braking levels, the locomotive engineer should reduce the level of braking and supplement with automatic train brakes when approaching turnouts or crossovers and should maintain the low level of dynamic braking until the front half of the train has cleared the turnout or crossover. The limits as to the number of axles and motors in dynamic braking for reliably safe operation depends upon:

1) Type of Equipment—Units with pin type couplers and no alignment control features must have bolster stops applied to allow operation in consists with units capable of high dynamic braking effort. The bolster stops limit bolster-to-truck-frame lateral clearance to ½ in. on each side, thereby limiting lateral rail forces when units are subjected to buff loads.
2) Particular track profile conditions.
3) Engineman's skill.
4) The practical limit for dynamic brake is often stated as "no more than 24 motorized axles may be operated in dynamic from the lead locomotive of the consist".

The dynamic brake should always be applied slowly and smoothly. When transferring from power to dynamic braking, the selector lever should be held in off position for 10 seconds. The 10 second delay must occur before indexing the selector lever to brake. The fact that the throttle may remain in idle position after indexing the selector lever to brake does not prevent a strong surge of braking effort. During operation under power the main generator delivers far more current at a far higher voltage than is required from the generator during dynamic braking. Consequently the magnetic fields set up during power operation are far stronger than are required during dynamic braking. When the selector lever is indexed from power to brake, transfer switches operate to connect the motor armatures to dynamic braking grids, and the brake power contactor connects the main generator to the traction motor fields. If the transfer is rapid magnetic forces have not had opportunity to decay, and an immediate strong surge of current is delivered to the traction motor fields, with a resulting sharp surge of braking current and braking effort. The sudden braking current can cause train run-in with resulting buff loads, and can also cause traction motor flashover. Even with the throttle in idle, the generator field contactor dropped out, and the dynamic brake regular and warning circuits ineffective, damage can occur.

The only effective means of preventing a current surge is to allow the generator field time to decay before indexing the selector lever to BRAKE. All EMD locomotives (built after March 1971) are equipped with a 5 to 7 second delay of dynamic brake. The delay is started when the throttle is placed in idle and affects only the unit equipped and not the other un-

equipped units which may be in the locomotive consist. The engineman must still be instructed to wait approximately 10 seconds between idle and dynamic brake. In addition, smooth application of dynamic brakes can be obtained by judicious handling of the braking level consistent with the operator's knowledge of the territory and of train length and weight.

The effectiveness of the dynamic brake depends on the ability of the traction motors, while acting as generators, to convert some of the energy of the moving train into electrical energy and to dissipate the electricity through resistance grids as heat to the atmosphere. The dynamic brake resistance grids have a fixed maximum horsepower capacity. Thus, the retarding force available from dynamic braking will vary with speed. A 6-axle locomotive unit with 3300-hp dynamic braking capacity of the extended range type can provide a maximum retarding force of 60,000 lb. from 6 mph up to a speed between 18 and 25 mph depending on the gear ratio. Above the latter speed, dynamic brake retarding force drops off sharply. Below 6 mph the capacity reduces to zero as speed reduces to 0 mph. Figures 89 and 90 and the following table illustrate the retarding force available from dynamic braking at various speeds for 4-axle and 6-axle units.

TABLE 4

DYNAMIC BRAKE RETARDING FORCE
3300 HP DYNAMIC BRAKE

	6 motored axles		4 motored axles	
Speed mph	Extended Range Dynamic, lb.	Standard Dynamic, lb.	Extended Range Dynamic, lb.	Standard Dynamic, lb.
6	60,000	14,400	40,000	9,600
12	60,000	30,000	40,000	20,000
24	60,000	60,000	40,000	40,000
30	48,600	48,600	32,400	32,400
40	34,000	34,000	24,000	24,000
50	28,800	28,800	19,200	19,200
60	24,000	24,000	16,000	18,000
70	20,400	20,400	13,600	13,600

The above data is expressed graphically in Figs. 89 and 90.

The amount of dynamic brake retarding force available in various degrees of intensity (throttle position) is shown on Figures 89 through 95. Note that there is some difference in the dynamic brake output between single unit and 4 unit consists at throttle positions under No. 8 setting.

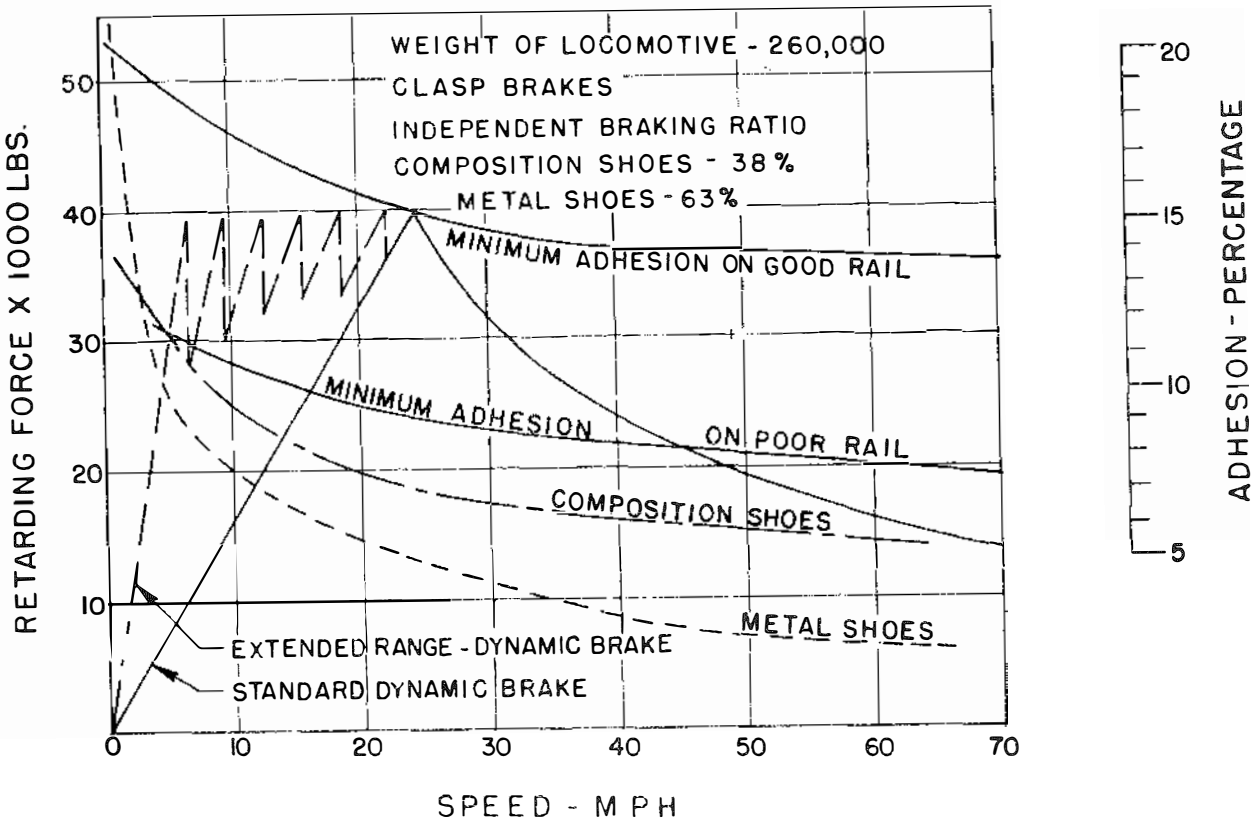
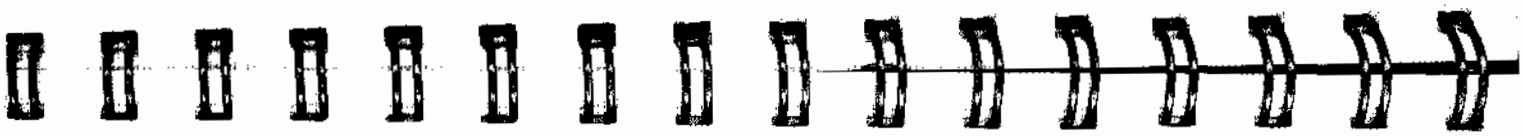
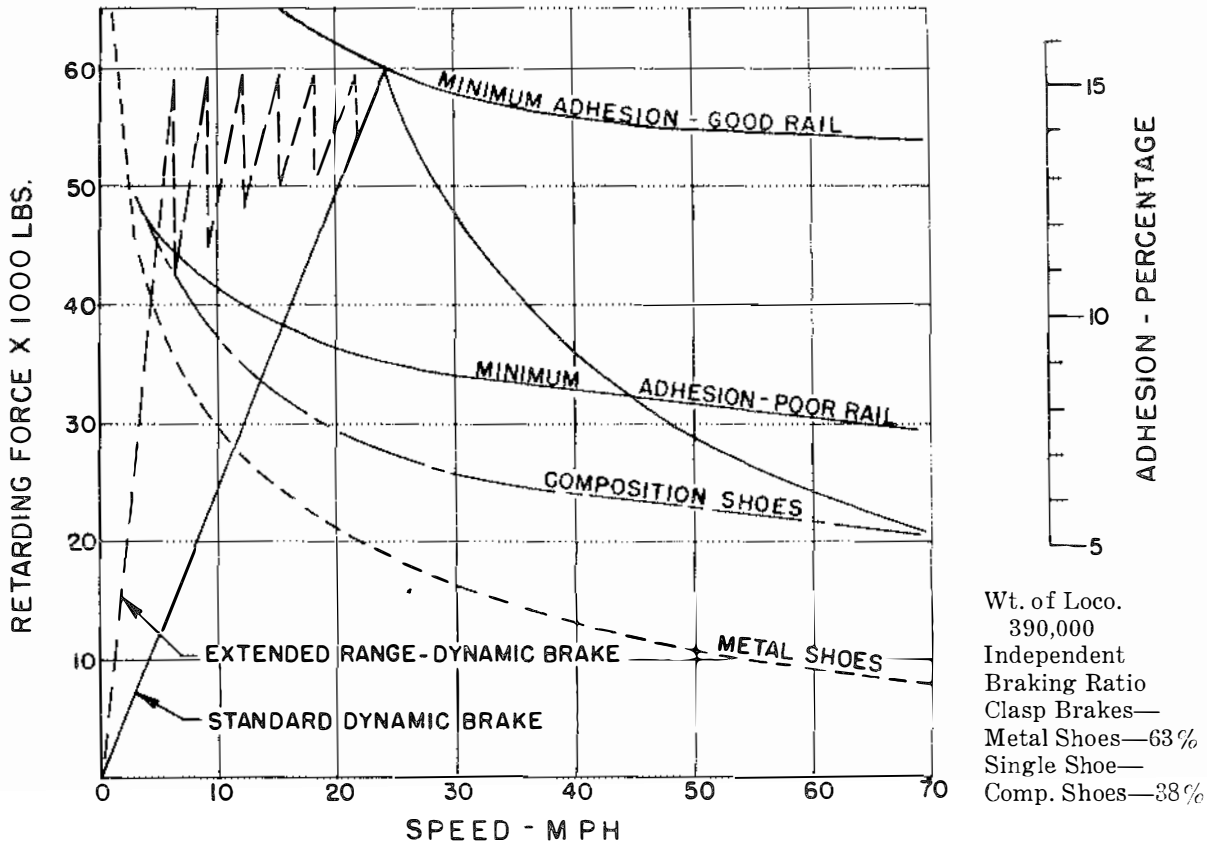


FIG. 89 COMPARISON OF RETARDING FORCE AVAILABLE IN DYNAMIC & INDEPENDENT BRAKING — 4 MOTORIZED AXLES





Wt. of Loco.
390,000
Independent
Braking Ratio
Clasp Brakes—
Metal Shoes—63%
Single Shoe—
Comp. Shoes—38%

FIG. 90 COMPARISON OF RETARDING FORCE AVAILABLE IN DYNAMIC & INDEPENDENT BRAKING — 6 MOTORIZED AXLES

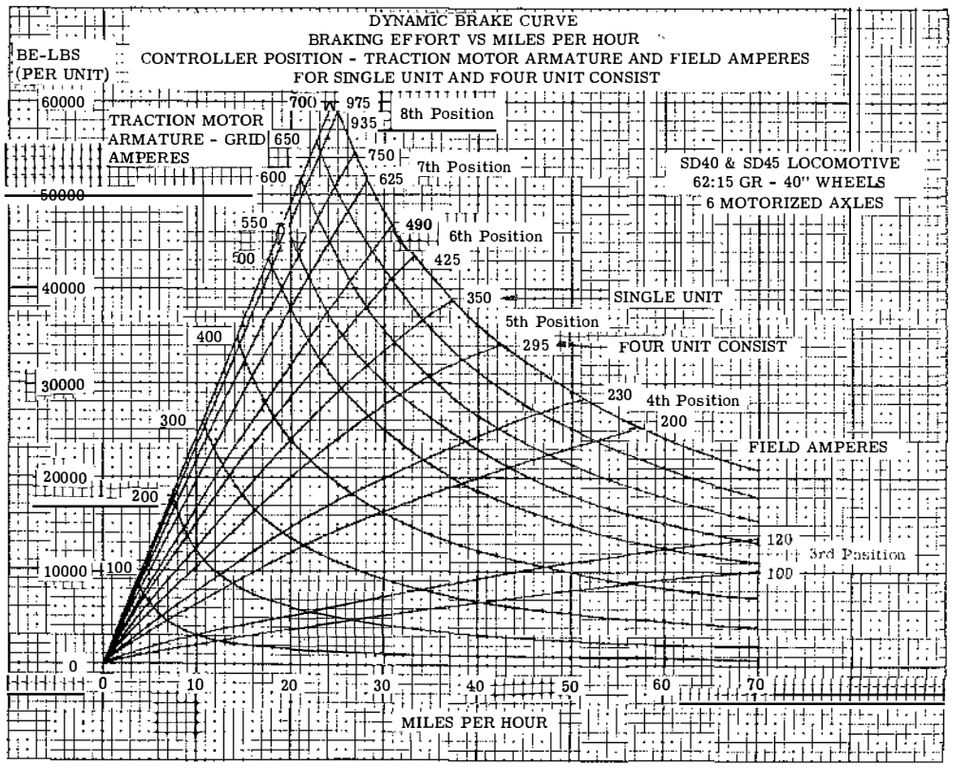

DYNAMIC BRAKE CURVE
BRAKING EFFORT VS MILES PER HOUR
CONTROLLER POSITION - TRACTION MOTOR ARMATURE AND FIELD AMPERES
FOR SINGLE UNIT AND FOUR UNIT CONSIST
BE-LBS
(PER UNIT)
TRACTION MOTOR
ARMATURE - GRID
AMPERES
8th Position
7th Position
6th Position
5th Position
4th Position
3rd Position
SD40 & SD45 LOCOMOTIVE
62:15 GR - 40" WHEELS
6 MOTORIZED AXLES
SINGLE UNIT
FOUR UNIT CONSIST
FIELD AMPERES
MILES PER HOUR

FIG. 91

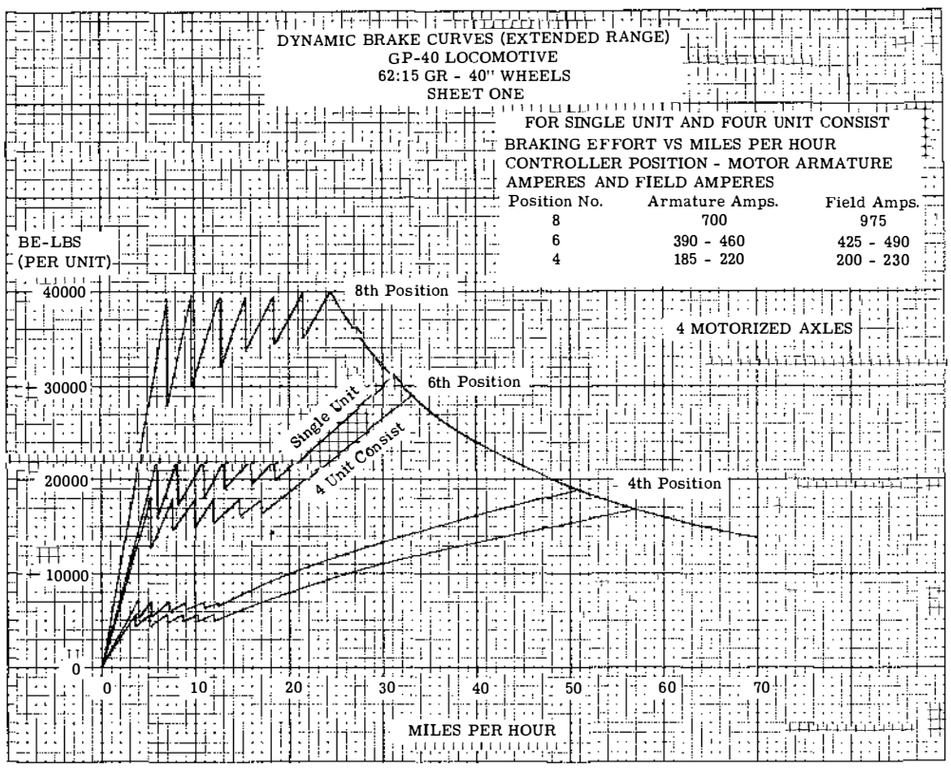

DYNAMIC BRAKE CURVES (EXTENDED RANGE)
GP-40 LOCOMOTIVE
62:15 GR - 40" WHEELS
SHEET ONE
FOR SINGLE UNIT AND FOUR UNIT CONSIST
BRAKING EFFORT VS MILES PER HOUR
CONTROLLER POSITION - MOTOR ARMATURE
AMPERES AND FIELD AMPERES
Position No. Armature Amps. Field Amps.
8 700 975
6 390 - 460 425 - 490
4 185 - 220 200 - 230
BE-LBS
(PER UNIT)
8th Position
6th Position
4th Position
Single Unit
4 Unit Consist
4 MOTORIZED AXLES
MILES PER HOUR

FIG. 92

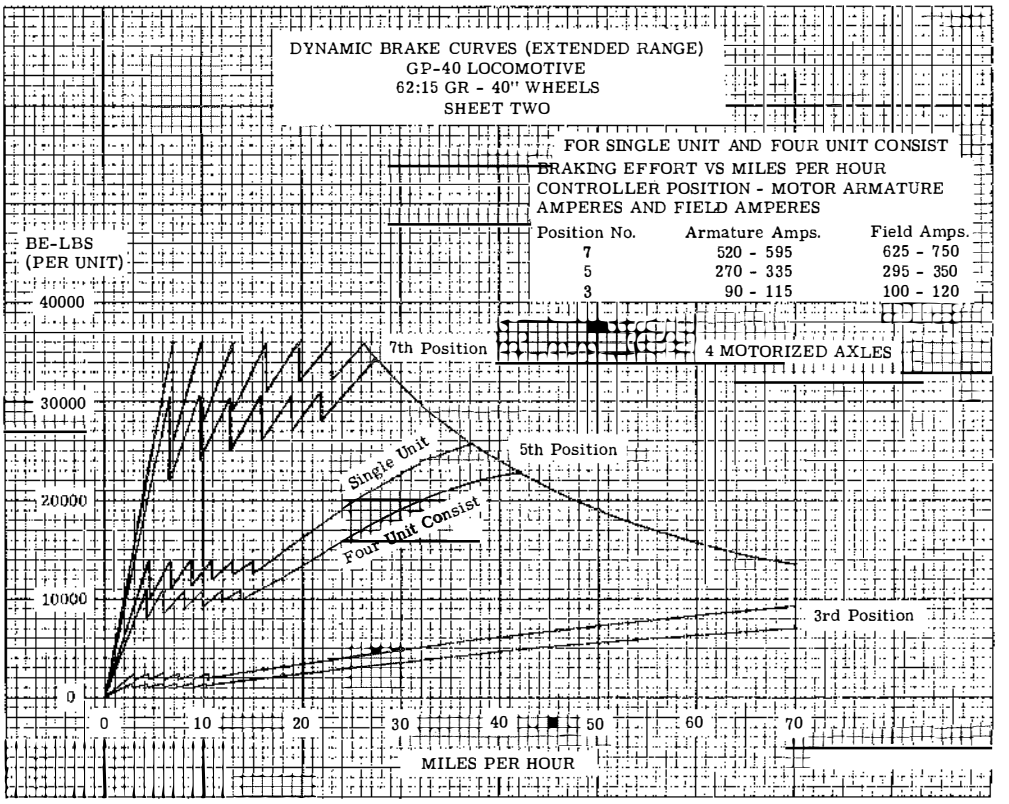

DYNAMIC BRAKE CURVES (EXTENDED RANGE)
GP-40 LOCOMOTIVE
62:15 GR - 40" WHEELS
SHEET TWO
FOR SINGLE UNIT AND FOUR UNIT CONSIST
BRAKING EFFORT VS MILES PER HOUR
CONTROLLER POSITION - MOTOR ARMATURE
AMPERES AND FIELD AMPERES
Position No. Armature Amps. Field Amps.
7 520 - 595 625 - 750
5 270 - 335 295 - 350
3 90 - 115 100 - 120
BE-LBS
(PER UNIT)
40000
30000
20000
10000
0
7th Position
4 MOTORIZED AXLES
5th Position
Single Unit
Four Unit Consist
3rd Position
0
10
20
30
40
50
60
70
MILES PER HOUR

FIG. 93

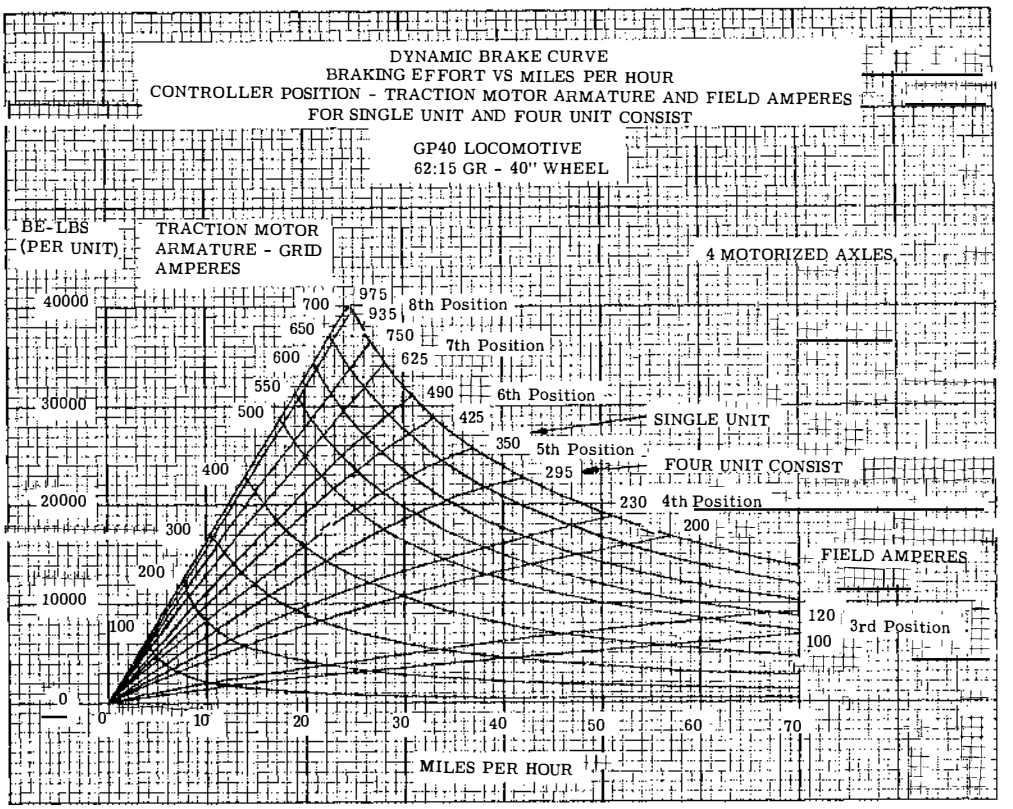

DYNAMIC BRAKE CURVE
BRAKING EFFORT VS MILES PER HOUR
CONTROLLER POSITION - TRACTION MOTOR ARMATURE AND FIELD AMPERES
FOR SINGLE UNIT AND FOUR UNIT CONSIST
GP40 LOCOMOTIVE
62:15 GR - 40" WHEEL
BE-LBS
(PER UNIT)
TRACTION MOTOR
ARMATURE - GRID
AMPERES
4 MOTORIZED AXLES
40000
30000
20000
10000
0
700
975
935
8th Position
650
750
7th Position
600
625
550
490
6th Position
500
425
SINGLE UNIT
350
5th Position
400
295
FOUR UNIT CONSIST
230
4th Position
200
300
200
FIELD AMPERES
100
120
3rd Position
100
0
10
20
30
40
50
60
70
MILES PER HOUR

FIG. 94

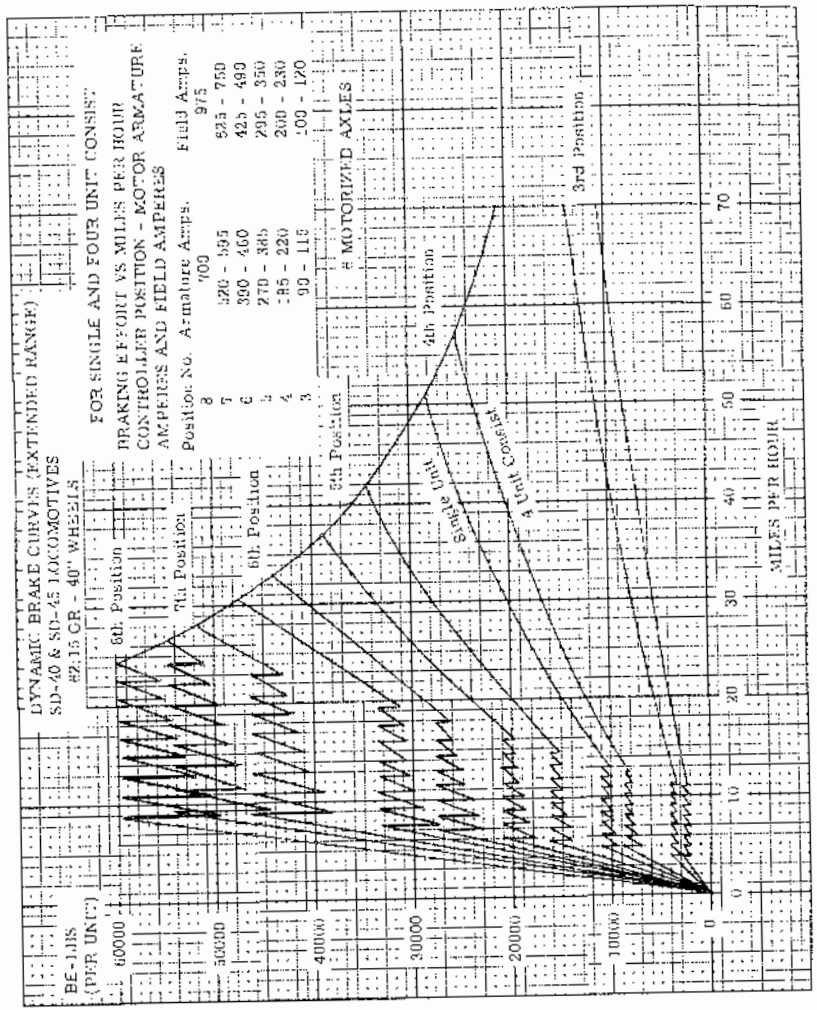


FIG. 95

GE GRID CURRENT TRAINLINE CONTROL AND EMD DYNAMIC BRAKE REGULATION SYSTEMS

GE and EMD use different systems for regulating the dynamic brake current when the dynamic brake handle is in the partial position. With the GE system, the handle position represents a certain grid current and regulates to this grid current value. With the EMD system, the handle represents a certain current in the fields of the traction motors and provides only a limiting type of regulation when grid current reaches 700 amps.

As can be seen from the GE curve, a handle position represents a certain grid current provided that the locomotive is above the speed of peak braking effort, approximately 22 mph on this particular curve. Above 22 mph the braking effort drops as the locomotive speed increases because, although the armature current remains constant, the field current decreases in order to maintain this current. Consequently, the braking effort decreases. If the train speed is increased because the grade becomes steeper, the braking current remains constant, but the braking effort decreases. In the 8th handle position, there is a slight taper off of this current at high locomotive speeds in order to limit the bar to bar voltage on the GE motor.

With the EMD system, as shown in Figure 95, the traction motor field current remains constant in a particular handle position up to the peak braking effort speed of that position. Beyond that speed, the locomotive is limited to 700 amperes, since this is the current rating of the braking grid. Therefore, if the train speed increased because the grade became steeper, the braking effort would also increase, along with the current in the grid, until the peak braking speed for that handle position is reached. Consequently, the train tends to inherently maintain a particular speed for the handle position.

For example, referring to Figure 95, if the engineer placed his brake handle in the No. 5 position at 18 mph (single unit curve) as the train speed rose to 20 mph, the braking effort would rise from 21,000 lbs. to 24,000 lbs., tending to try to keep the train at the 18 mph speed. Therefore, the engineer would have to take less corrective action by moving his handle in order to maintain the 18 mph. If 24,000 lbs. would hold the train speed on this particular grade and he wanted to go faster, he could reduce his handle position to position No. 4. Now the train would balance out at 40 mph. Bringing his handle back to a higher position would make the train balance out at a lower speed.

It should be pointed out that, with the EMD system, if the train was going 50 mph, moving the brake handle back from position 8 to position 4 would not decrease the braking. Only below position 4 would the braking start to decrease. This would apply down to position 5 at 37 mph. With the GE system, the braking current decreases with any reducing movement of the dynamic braking handle.

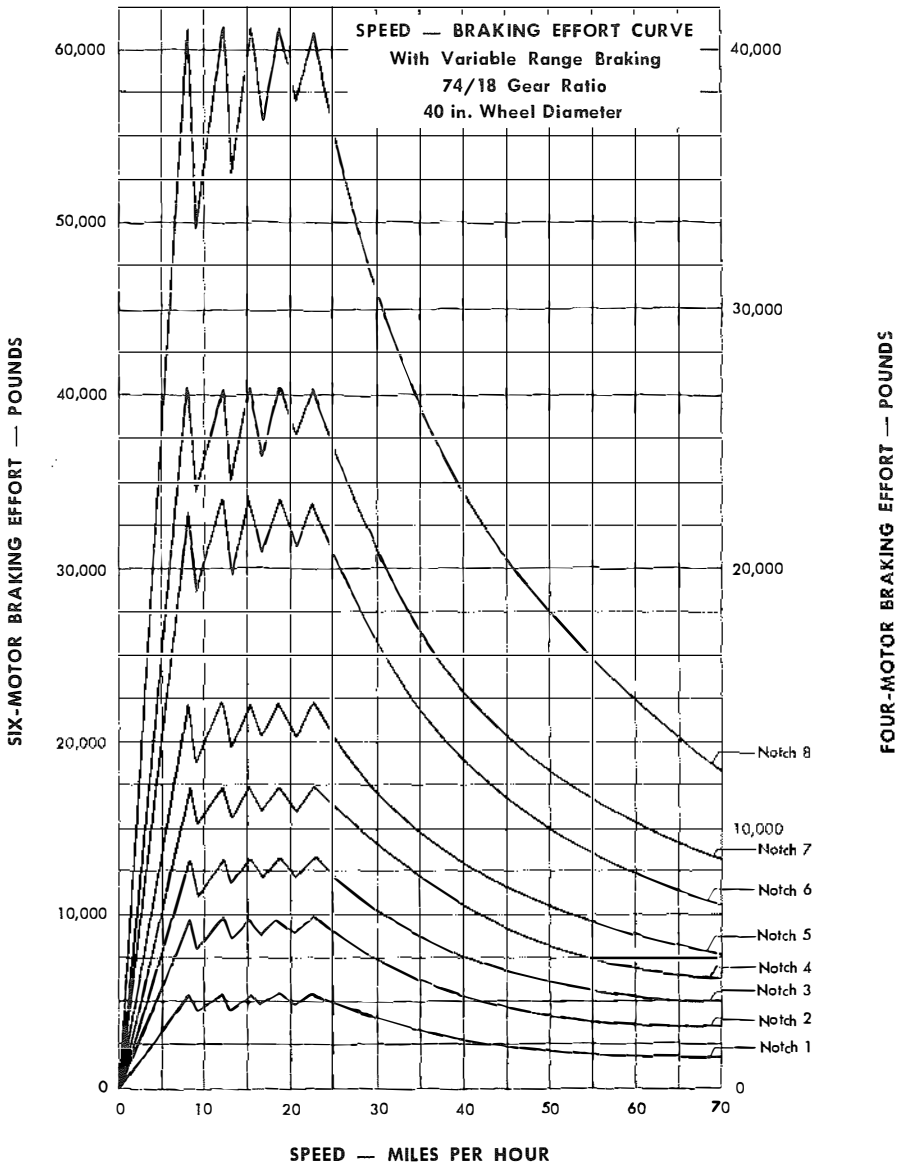


FIG. 96 FOUR AND SIX-MOTOR BRAKING EFFORT — POUNDS
GE LOCOMOTIVES

Because of the basic differences in the two systems as outlined above, operation of a mixed consist of EMD and GE locomotives can result in unequal braking efforts between the two types of units when operating under most conditions of brake handle positions below position 8. For example, at 40 mph with the brake control at position 5, the EMD units will have approximately 36,000 lbs. braking effort (Figure 94) while the GE units will have 13,000 lbs. braking effort. (Figure 95)

To gain appreciation of what this means consider a 4-unit consist of 6-motor locomotives handling a train of 6,000 trailing tons. Refer to Figs. 95 & 97.

At 50 mph, maximum dynamic brake retardation of 28,800 lbs. per locomotive unit would allow a total retarding force of 115,200 lbs. Since the total train weight will be approximately 6,800 tons, the train retarding force will be approximately 16.9 lb. per ton. This is equivalent to a speed reduction of 0.19 mph. As the speed reduces and the dynamic braking force increases, greater retardation will be available. For example, assume the speed has been reduced to 25 mph and maximum dynamic brake is applied. The dynamic brake retarding force for each unit will be approximately 57,000 lb. and the total applied to the train will thus be approximately 228,000 lb. This will provide a retarding force of approximately 33.5 lb. per ton and speed reduction ability of about 0.37 mphs. Obviously, from the optimum speed and particularly with extended dynamic, the maximum dynamic retarding force for these units could be approximately 240,000 lb. down to 6 mph. As can be seen, if this same locomotive consist were handling a train of half of the trailing weight, nearly twice the retarding effect would be expected from the dynamic brake, as illustrated for the 3000-ton train in Figure 97.

On the lower part of Fig. 97, there is a comparison of the retarding effect of dynamic brake and the train air brake. Retardation of the train air brake is shown for various brake cylinder pressures. Note that with a 100-car, 6000 trailing ton train, the air brake at 10 psi brake cylinder pressure (a minimum service reduction) is equal or better than dynamic brake only at speeds above 50 mph and below 7 mph. At 20 psi brake cylinder pressure (approximately 10 psi brake pipe reduction) the train air brake is more effective than dynamic at all speeds. However, if a minimum brake pipe reduction giving 10 psi brake cylinder pressure and dynamic brake are coordinated, the train retardation will be about equal to that obtained with 20 psi brake cylinder pressure. Dynamic and air brakes can be used during slowdowns and stops if properly coordinated. Obviously, the work done by the dynamic reduces brake shoe work required from the train air brakes.

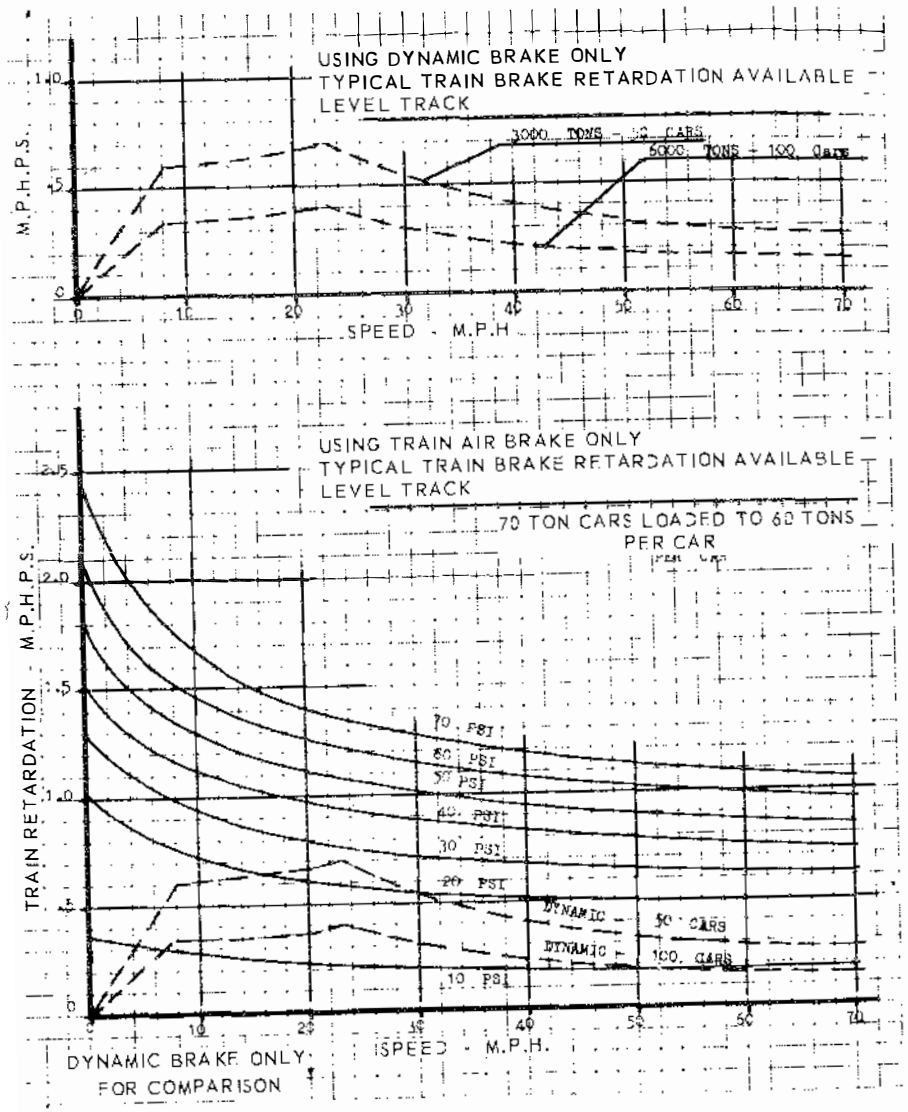


FIG. 97 TRAIN RETARDATION WHEN USING DYNAMIC BRAKE OF 4-6 LOCO UNITS AS COMPARED TO TRAIN BRAKE WHEN HAULING 50 CARS OR 100 CARS

The principal use of dynamic and air brakes simultaneously is when operating on descending grades. An example of this follows:

Number of cars	100
Trailing tons	10,000 tons
Locomotive-four (4) 6-axle units	800 ton
Total train weight	10,800 tons
Grade-descending	—2%
Speed	24 mph
Gravity force—downgrade	432,000 lb.
Dynamic brake retarding force (60,000 lb./unit)—total	240,000 lb.
Air brake retarding force required to balance grade	192,000 lb.
Avg. minimum air brake retarding force per car	1,920 lb.
Normal air brake retarding force per car (to allow ¼ of available dynamic braking effort to be used)	2,520 lb.

As noted above a total train retarding force of approximately 432,000 lbs. is required to balance this grade. Even if all of this force were available in the locomotive consist at the head end, the concentration of this large, compressive force will probably give difficulty in the head portion of the train. A train air brake pipe reduction of approximately 10-14 psi would probably be required in descending this grade. The amount of reduction will depend on characteristics of the cars, brake equipment, weather effects, specific gradients and curvature. Since the train resistance will vary on different portions of the run it is usually impractical to plan braking using maximum dynamic brake at all times. The dynamic brake intensity can be varied rather quickly in relation to the train brakes and therefore it is more practical to use this feature of the dynamic brake to provide the necessary changes in retarding force required to hold train speed steady.

Since the ultimate aim of the engineman is to maintain a constant speed on the grade, regardless of change of grade percentage, curvature, etc., the train brake pipe reduction should be such that by varying the dynamic brake between minimum and maximum the train speed can be held with little if any variation. The combination of train air brake plus the dynamic brake should be such that on the heaviest portion of the grade, the train air brake application plus the maximum dynamic brake will hold the train speed within established limits. This means that the dynamic brake can be varied to take care of the changes in train resistance due to grade curvature, etc.

If the air and dynamic brakes are applied to the locomotive simultaneously, in many cases the total retarding force may exceed rail adhesion

and wheel slipping or sliding may result. For example, Figure 90 shows that at 10 mph the retarding force of the independent brake is approximately 30,000 to 37,000 pounds depending on whether cast iron or composition shoes are used. The standard dynamic retarding force at the same speed would be approximately 24,000 lbs. If these forces were combined, the total resulting retarding force would be from 54,000 to 61,000 lb., or well above the available adhesion on poor rail and approaching the available adhesion on good rail.

Therefore, it is advisable to provide an automatic feature (dynamic brake interlock) in order to prevent an automatic service brake application on the locomotive when the train brakes are applied during dynamic braking. The dynamic brake interlock is a magnet valve which is energized or de-energized in relation to the dynamic brake controls. The magnet valve in turn prevents the automatic service brake from applying and will release the service brake if already applied. This can be done to provide either of the following features:

a. The service brake *will* re-apply when dynamic brake is released.
b. The service brake *will not* re-apply when dynamic brake is released.

When an emergency brake application is made, the dynamic brake interlock is nullified, and the air brake is allowed to apply fully.

The option of using the independent brake is available at all times, whether or not dynamic brake is in effect. However, considerable judgment must be exercised when using the independent brake, while the dynamic brake is also being used. The use of the independent brake is generally employed at lower speeds in order to supplement the standard dynamic effort which rapidly fades as speed diminishes below the most effective point.

When operating with extended range dynamic brake equipment locomotives in a consist, it is important that the engineman be aware that the dynamic brake is effective down to a much lower speed on these units. For example, Fig. 90 shows that the standard dynamic brake develops a maximum retarding force at approximately 24 mph and recedes rapidly at greater or lesser speeds whereas the extended range of dynamic brake retains a high retarding force down to approximately 6 mph.

To minimize the possibility of sliding wheels, extending range dynamic brake locomotives are equipped with a pressure switch which releases the extended range portion of the dynamic brake whenever brake cylinder pressure exceeds 15 psi.

Successful train handling on grades involves not only a knowledge of the train and locomotive consist characteristics, but the location, degree, and length of curvature and grade ahead. In other words, the engineman must learn to plan ahead. Good planning, for example, involves reducing the train speed on the straighter, heavier portions of the grade slightly below the speed restriction for up coming curves so that the train can round the curves without having to have maximum dynamic brake applied. This will avoid excessive draft gear and lateral rail forces.

CHAPTER IV — REMOTE CONTROL SYSTEMS

Efficient railroad operation requires the movement of large quantities of goods under all types of conditions. Unfortunately terrain and weather have often time impaired the movement of long trains and, therefore, lessened the desired train tonnage. There have been two systems developed recently which have aided in lengthening trains. The two systems are Remote Control Equipment and Repeater Relay System. Remote Control Equipment utilizes a second locomotive consist located back in the train, which receives its power and brake commands via radio signals from the head end locomotive. The Repeater Relay System is solely an air supplier also located back in the train which operates off pneumatic signals received through the brake pipe.

One of the key advantages of both of these systems is their ability to allow increased train length during cold weather. Fig. 98 represents train length versus air temperature for the two above mentioned systems as compared to a standard train consist. It can be seen that the Repeater Relay allows train length to increase by about half and the Remote Control Equipment allows the train to be more than twice as long as a standard train. A more detailed description of the two systems follows.

REMOTE CONTROL EQUIPMENT

Remote control equipment for locomotives is one of the more recent advancements in train handling. The AAR has designated this type of system as RCE-1.

RCE-1 enables an engineman on the lead locomotive unit to control the locomotive functions of throttle, dynamic brake, air brake application — both automatic and independent—and sanding, on remote units of a locomotive consist located anywhere in the train, through a coded space radio communication system.

Train operation with RCE-1 requires only that the head end locomotive of the lead consist be equipped with the required control equipment and radio coded communication system transceivers. The remote consist is controlled by a remote system which receives its commands from the lead unit via coded radio signals. In both locations the additional locomotive units making up the consist require no special equipment to be used.

The specific equipment required for RCE-1 operation is:

1. Brake control console
2. System logic
3. Brake control manifold
4. System control console
5. Coding and communication system
6. Interconnecting wiring to existing locomotive controller and alarm systems and RCE-1 components

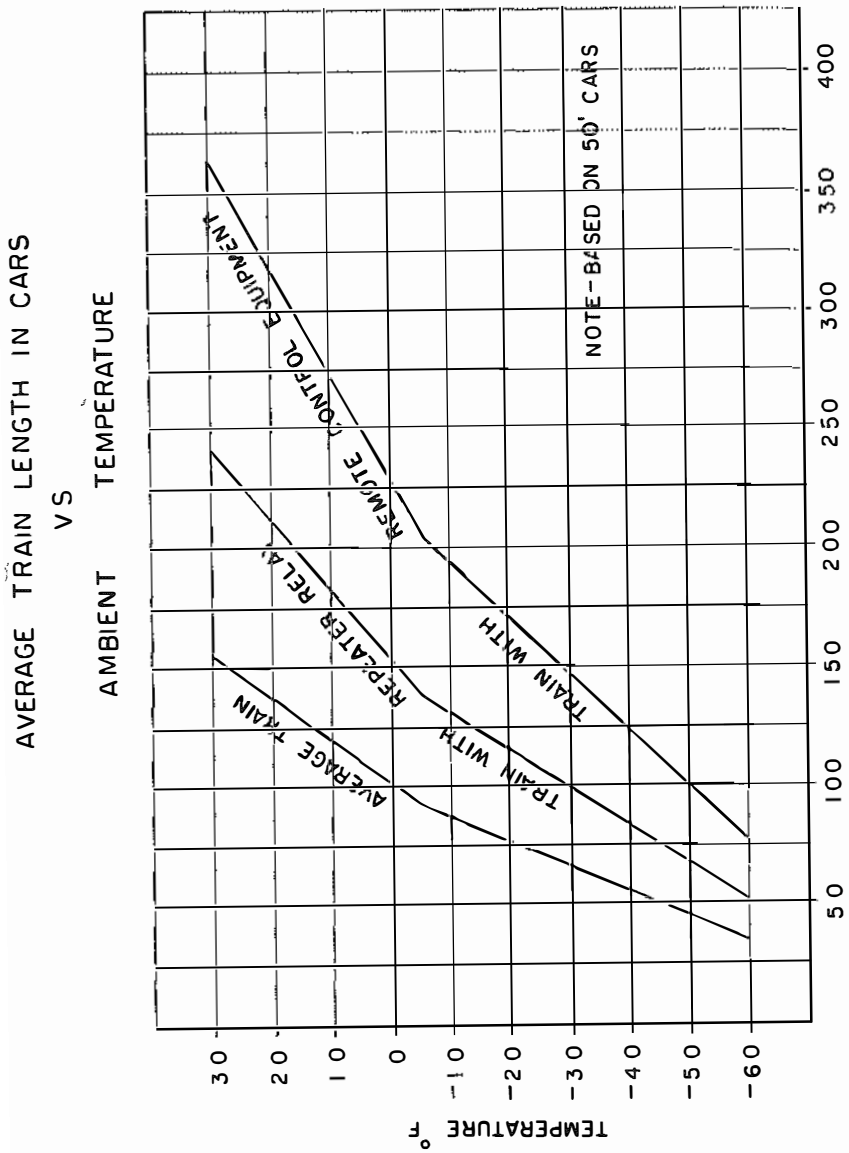


FIG. 98 TRAIN LENGTH, CARS

The preceding is required on those units which will be used for control units of the lead consist. The controlling unit of the remote consist need not have the system control console or brake control console.

The function of each of the components is to provide the following:

1. Brake Control Console

In RCE-1 operation the push button panel replaces the pneumatic brake valve to provide automatic and independent brake applications and releases, as well as an emergency application that is simultaneously actuated by electronic and pneumatic signals. The brake control console supplies the "system logic" with electrical signals upon depression of any of the lighted push buttons. Although not a brake valve itself the brake console will activate the necessary electrical and pneumatic components to pilot the existing brake valve and the associated pneumatic devices.

2. System Logic

The system logic unit accepts electrical control signals on the locomotive from the locomotive controller, brake control console, system control console and coding and communication system. It co-ordinates this information and provides the necessary outputs for control of the train. This unit is required on both lead and remote controlling locomotives.

3. Brake Control Manifold

The brake control manifold permits electrical control of the air brake system on both the lead and remote units. Upon receiving electric impulses from the logic outputs, magnet valves energize or de-energize to direct air flow to and from standard air brake components. The manifold responds in time with operations performed at the brake control console to provide automatic and independent brake applications and releases, and emergency applications. The manifold also provides pneumatic-electric signals through the use of pressure switches for important functions, including override sensing, feed valve operation, break-in-two emergency transmission and remote independent brake application indication.

4. System Control Console

The system control console is required only on the controlling locomotive of the lead unit consist. The console continuously indicates the status of the remote locomotive and provides a visual indication of response with audio indication of alarm conditions in the remote unit such as low oil, ground relay, wheel slip, etc. In addition, there are push buttons, indicator lights and selector switches which permit the engineman to control the remote consist throttle and dynamic functions synchronized with or independently of the lead locomotive where operating rules permit.

5. Coding and Communication System

The coding and communication system is a solid state system required on both controlling lead and remote locomotive units. It accepts information from the system logic unit for coding and transmittal by the radio link to the other locomotive unit. It likewise receives transmissions,

decodes, and furnishes this information to the system logic unit for action or direction to selector and indicator console for display.

6. Interconnecting Wire

The interconnecting wiring is provided by plug-in cables to the various components of the system. Throttle and dynamic brake functions, reverser, selector functions and signal wire are interconnected with existing wire in the locomotive unit controller and electric cabinet.

Operating Advantages:

The remote location of controlled power and nearly instantaneous response by remote units to command signals initiated on the lead locomotive provides operational advantages that can greatly facilitate freight train operation.

Train Charging:

The charging time of train air systems is greatly reduced by having air supplied to the brake pipe not only at the head end of a train, but at the remote location. This ability can permit a reduction of 75% or more in train charging time, depending on the location of the remote unit, over a similar train being charged only by the lead unit consist.

Train Starting:

The flexibility of independent operation of remote consists permit the engineman to have fine control of slack when starting trains in undulating or multiple curved locations. Since the remote locomotive consists may be either synchronized with the lead units or independently controlled by the engineman, he has the advantage when operating in synchronism of having his tractive effort more uniformly distributed within the train in proportion to the starting load. The more even distribution of power reduces drawbar stress on lead locomotives and head-end cars.

Train Operation:

The RCE-1 systems facilitate the use of train brakes to control slack action when operating in undulating terrain. The rapid response to brake applications and releases coupled with uniform braking force throughout the train control slack action to a degree not heretofore possible.

Trains may safely be braked against power, where operating rules permit, to control train speeds without changing throttle positions because of the very fast brake application and release times and resulting slack control. The rapid release times materially reduce sags and dips in train speed providing higher average running speeds.

For operation over heavy grade territory, the flexibility of train brake control with the rapid application times made possible with RCE-1 control facilitate train handling by providing prompt response to brake pipe reductions. In those instances where total or partial dynamic brake loss should occur on grade operations, prompt response of train brakes with uniform braking power on the train give the engineman complete control of the train to a degree not previously known.

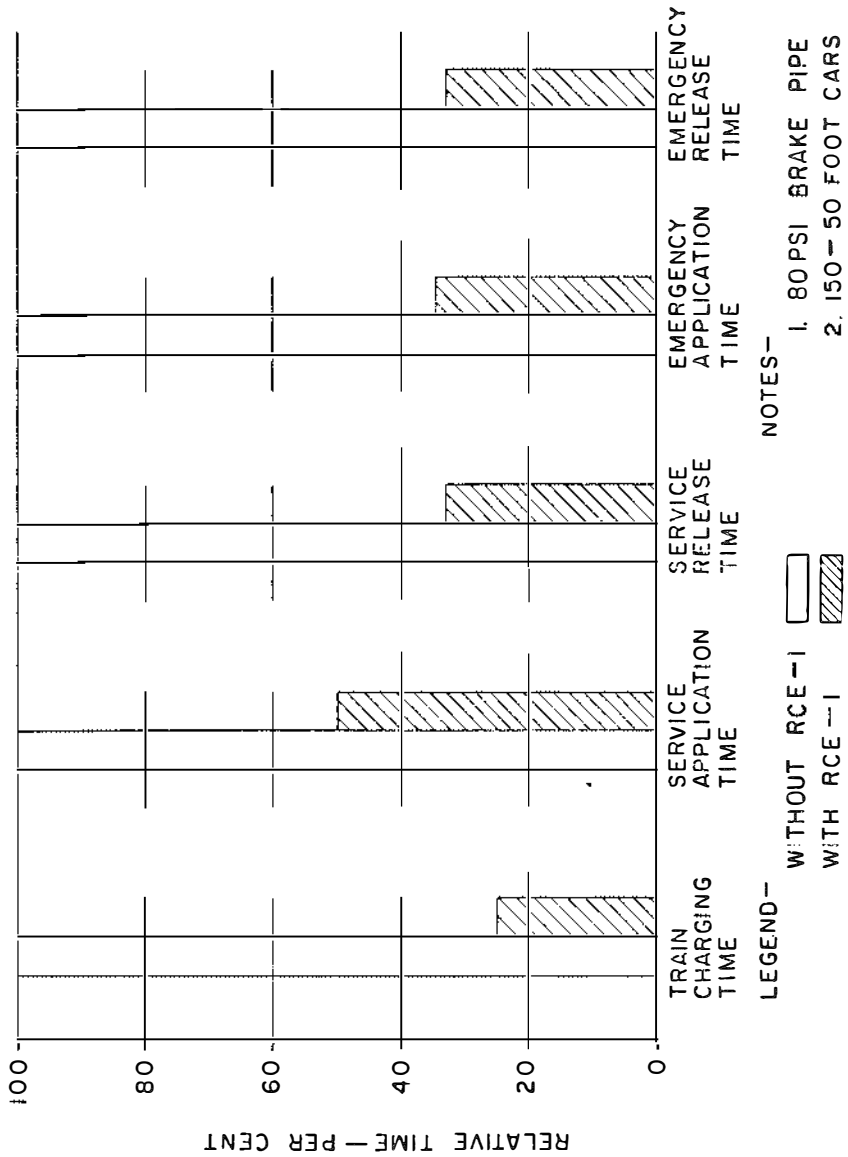


FIG. 99

Of particular interest are train brake response times. The RCE-1 system can provide service applications in half the time of conventionally braked trains. Similarly, release times of service applications can be reduced by two-thirds with RCE-1, system. Emergency applications and releases can be reduced by two-thirds and more on trains with additional leakage. The response times as tabulated, graphically, below, were found with a 150-car train with the remote unit at car 100. Other train lengths and remote unit locations may improve or lessen comparative train performance. The accepted standard AAR practices governing the use of radio controlled locomotive operation are shown in Appendix.

THE REPEATER RELAY SYSTEMS

The Repeater Relay System is an equipment composed of various components which function to relay brake pipe reductions or increases to a rear portion of a train. The repeater relay is entirely pneumatic in its operation, and receives a pneumatic signal from the forward portion of the train. This can prove to be of considerable value in long train operation.

The repeater relay equipment may be obtained in two versions. One is called the L-1, and the other is termed FC-1. The L-1 is designed for installation in a locomotive unit having its own air supply. The FC-1 freight brake repeater unit is designed for installation in a freight box car. This unit has its own air supply, which includes a 3CEBE Compressor Unit which comprises a 3CBC air compressor, diesel engine unit, fuel tank, aftercooler, governor and main reservoirs. The pneumatic repeater unit is common to both the L-1 and FC-1 repeater relay systems and consists of the following components: a positioning valve, the function of which is to condition the equipment for the proper direction of air flow; and the repeater relay valve which supplies air to the rear portion of the train, during charging, recharging after applications, and to supply normal leakage while running over the road. The repeater relay also exhausts brake pipe pressure from the rear portion of the train in response to a reduction on the forward portion of the train. Also required are a variable orifice valve and cut-off valve along with 2 two-step by-pass check valves. The variable orifice valve proportions the rate at which air can flow through the repeater relay, and the cut-off valve cuts off the flow of feed valve air to the repeater relay and the rear portion of the train in case of an emergency application. The two-step by-pass check valves allow an emergency application to pass through the repeater relay unit in either direction.

The air compressor which has a capacity of 203 cfm at 660 rpm is driven by a diesel engine which is automatic after being started. An indicator light is provided to indicate when main reservoir pressure is low.

Generally speaking, the best placement for the repeater relay equipment in the train is approximately in the middle of the train. This placement will divide the air demand nearly equally between the headend locomotive and the repeater relay unit. This placement of the repeater relay unit will also provide more prompt brake applications, since the amount of brake pipe air to be exhausted will be nearly equal in each half of the train.

The repeater relay system offers the following advantages in train operation:

1. It provides much faster initial charging of trains at terminals.
2. It reduces the taper or gradient in brake pipe pressure between the front and rear of the train, especially in cold weather when leakage is greater. This provides more uniform braking throughout the train and reduces slack action due to run-ins because of less braking on the rear of the train.
3. The repeater relay system provides faster brake releases because of a much more rapid increase in brake pipe pressure in all portions of the train.
4. Brake applications will be speeded up materially since brake reductions can be effected more rapidly because the repeater relay is assisting in reducing brake pipe pressure on the rear portion of the train resulting in a faster reduction at the brake valve of the locomotive at the front of the train.

The accompanying block diagram, Fig. 100, shows a comparison of the time required for a service application (10 psi brake cylinder pressure) with 150 AB and ABD equipped cars with and without the A-1 Repeater Relay. Also, the time to begin release on the last car for the same train is shown. In addition, a comparison of the time required to recharge to 74 psi in the rear car brake pipe (car 150) after release of a 20 psi brake pipe reduction.

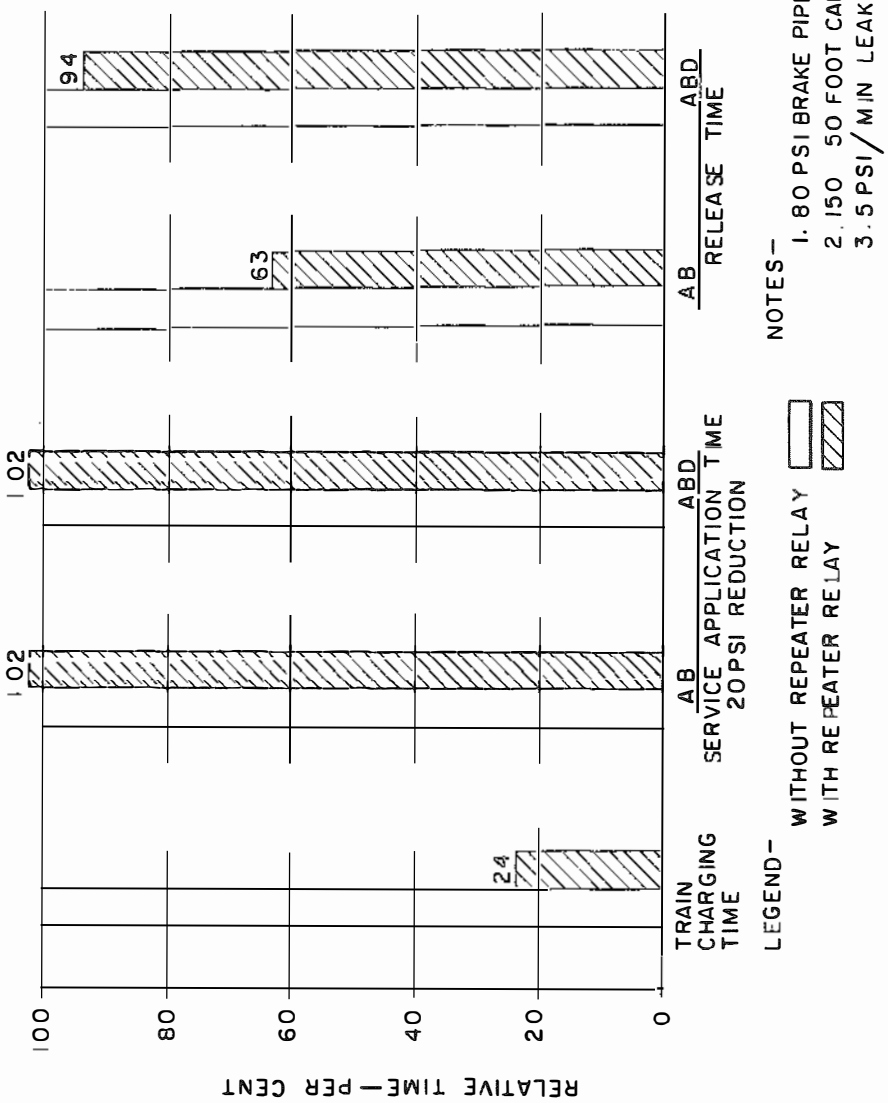


FIG. 100

CHAPTER V — HANDLING FREIGHT TRAINS

General

The information in this section covers the basic requirements essential for the proper handling of freight trains. Freight train handling involves the coordination of many factors which command attention, obedience to the local operating rules and the exercise of good judgment.

A. Checking Out Locomotive

To insure that a locomotive is properly conditioned for service, the following should be checked:

1. Exterior—Ground Inspection
   a. All units in consist should have sufficient fuel.
   b. No leakage of fuel oil, lubricating oil, water or air should be apparent.
   c. Proper hose connections should be made between units of multiple consists.
   d. Proper positioning of all cut-out cocks and angle cocks, including brake cylinder cocks.
   e. Moisture drained from main reservoirs and automatic drain valves operative.
   f. Satisfactory condition of brake shoes and rigging.
   g. Multiple unit control cable jumpers properly installed between units.
2. Engineroom Inspection
   a. Sufficient air compressor lubricating oil.
   b. Proper water level in cooling water sight glass.
   c. Properly position all valves.
   d. Observe for any leakage of oil, water or air.
3. Cab Inspection—Lead Unit
   a. All fuses, switches and circuit breakers in proper position and operating order.
   b. Control and fuel pump ON.
   c. Reverser handle inserted.
   d. Throttle in idle.
   e. Independent brake valve handle inserted—place in full application position.
   f. MU-2-A valve, K-type Rotair, or double-ported cut-out cock properly positioned for LEAD operation.
   g. Automatic brake valve handle inserted and properly positioned.
   h. 26-L automatic brake valve cut-off valve in proper position: CUT-IN on two position type and FRGT on three position type. Do not place cut-off valve in PASS position when operating a freight train.
   i. With 24-RL or other types of locomotive brake equipment, make certain brake pipe cut-out cock is cut-in.
4. Trailing Unit Cab Inspection
   a. See that all fuses, switches and circuit breakers are in proper position.

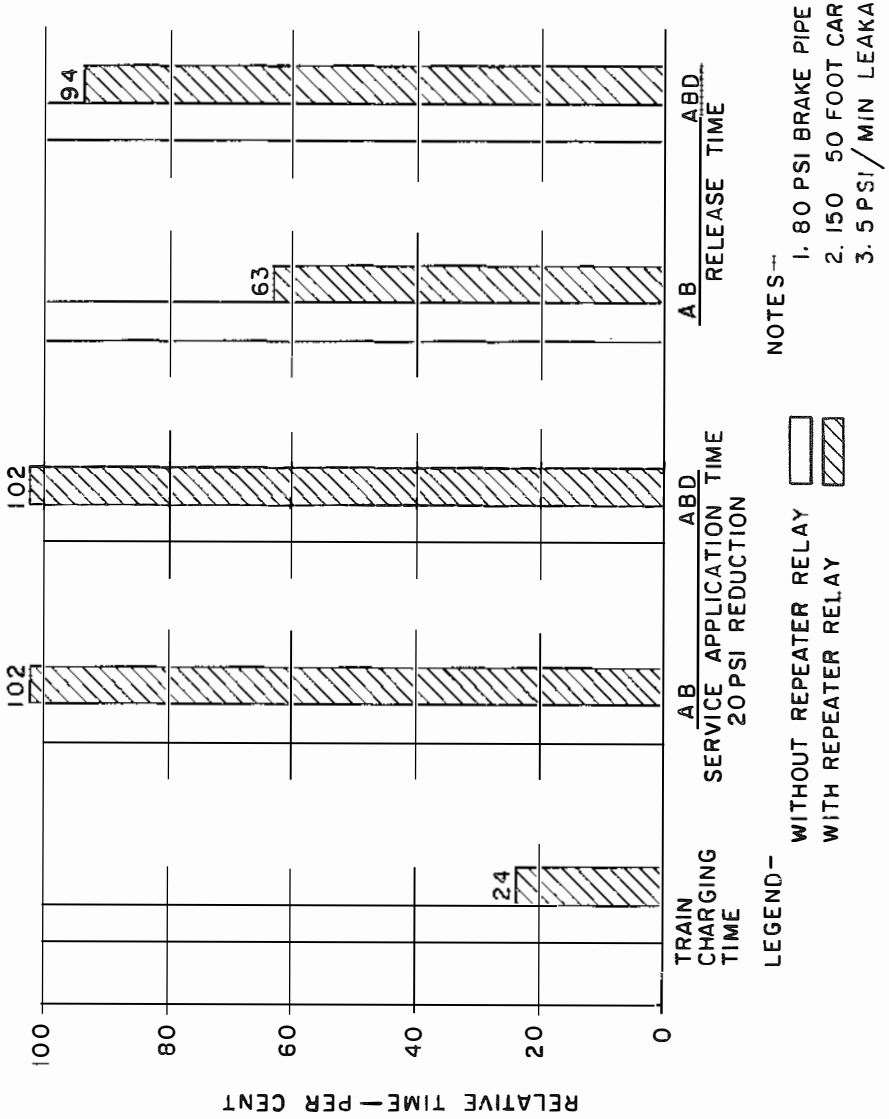


FIG. 100

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   c. Proper hose connections should be made between units of multiple consists.
   d. Proper positioning of all cut-out cocks and angle cocks, including brake cylinder cocks.
   e. Moisture drained from main reservoirs and automatic drain valves operative.
   f. Satisfactory condition of brake shoes and rigging.
   g. Multiple unit control cable jumpers properly installed between units.
2. Engineroom Inspection
   a. Sufficient air compressor lubricating oil.
   b. Proper water level in cooling water sight glass.
   c. Properly position all valves.
   d. Observe for any leakage of oil, water or air.
3. Cab Inspection—Lead Unit
   a. All fuses, switches and circuit breakers in proper position and operating order.
   b. Control and fuel pump ON.
   c. Reverser handle inserted.
   d. Throttle in idle.
   e. Independent brake valve handle inserted—place in full application position.
   f. MU-2-A valve, K-type Rotair, or double-ported cut-out cock properly positioned for LEAD operation.
   g. Automatic brake valve handle inserted and properly positioned.
   h. 26-L automatic brake valve cut-off valve in proper position: CUT-IN on two position type and FRGT on three position type. Do not place cut-off valve in PASS position when operating a freight train.
   i. With 24-RL or other types of locomotive brake equipment, make certain brake pipe cut-out cock is cut-in.
4. Trailing Unit Cab Inspection
   a. See that all fuses, switches and circuit breakers are in proper position.

b. At locomotive control station; fuel pump, generator field and engine run switches OFF, throttle in IDLE, selector in OFF, reverser in NEUTRAL and handle removed.

c. 26-C automatic brake valve in HANDLE OFF and handle removed (if removable type), cut-off valve in CUT-OUT position.

d. 24-RL or other type automatic brake valve handle removed, (if removable type). If not removable, insert pin in proper position, otherwise, place handle in release position.

e. MU-2-A valve or K-2 type Rotair or double ported cut-out cock in proper position (see table) for type of MU brake operation required.

5. Make sure hand brakes are released on all units of the consist.

Type Of Service	Automatic Brake Valve	Independent Brake Valve	Brake Valve 26-F-B	Dead Engine Cutout Cock	26D Control Valve	26F Control Valve	MU2 Valve	Overspeed Cutout Cock	Deadman Cutout Cock
SINGLE LOCOMOTIVE EQUIPMENT									
Lead	Release	Release	Pass / Exh	Closed		Graduated / Direct	Lead	Open	Open
Remote Locomotive	Handle Off	Release	Closed	Closed		Graduated / Direct	Lead	Open	Open
Shipping Dead In Train	Handle Off	Release	Cutout	Open	Relief Valve At Control Reservoir 73 ± 2 Lbs	Direct	Lead	Closed	Closed
Radio Control Lead Unit	Release	Release	Lead	Closed		Direct	Lead	Open	Open
Radio Control Remote Unit	Release	Release	Lead	Closed		Direct	Lead	Closed	Closed
MULTIPLE LOCOMOTIVE EQUIPMENT AND EXTRAS									
Lead	Release	Release	Pass / Exh	Closed		Graduated / Direct	Lead	Open	Open
Trail	Handle Off	Release	Cutout	Closed		Graduated / Direct	Trail 6 or 26* / Trail 6	Open	Open
Shipping Dead In Train	Handle Off	Release	Cutout	Open	Relief Valve At Control Reservoir 73 ± 2 Lbs	Direct	Lead	Closed	Closed
Double Heading	Handle Off	Release	Closed	Closed		Graduated / Direct	Lead	Open	Open
Lead Locomotive									
Operative Station	Release	Release	Pass / Exh	Closed		Graduated / Direct	Lead	Open	Open
Non-Operative Station	Handle Off	Release	Closed						

*Whenever the MU2A valve is in "Trail 6 or 26" position and if the actuating trainline is not used, then the actuating end connection cutout cock must be open to atmosphere; or to prevent the inadvertant loss of air through the trainline, a reversed bolt in the actuating line.

B. Preparation of Locomotive Consist

For many years locomotive units were designed and built for specific types of service such as passenger, freight, or yard switching. At that time it was seldom, if ever, necessary to couple units together of unlike design and unlike air brake systems.

With the advent of General Purpose and Special Duty Road Switching Locomotives, their operating characteristics and design accommodated a wide variety of services. To increase flexibility and utilization, such units were called upon to perform in multiple with other model locomotives and other air brake systems.

Unfortunately two of the principal locomotive brake equipments in use at that time were incompatible in MU operation. These were the 24-RL brake equipment commonly referred to as a two-pipe system and the 6-BL or 6-SL equipment commonly referred to as a one-pipe system.

The 24-RL brake equipment employs two trainline pipes for independent brake control: the independent application and release pipe (No. 20), and the actuating pipe (No. 13).

During an independent brake application the independent application and release pipe is charged and the brake application is relayed to the brake cylinder. The release is accomplished by exhausting the air in No. 20 line. During an automatic application No. 20 pipe is not charged.

When the automatic train brakes are applied, the locomotive brakes can be released by depressing the independent brake valve handle. This action charges the actuating pipe which permits the individual release of the automatic application at each locomotive in the consist.

The 6-BL or 6-SL air brake employs a single trainline pipe for independent brake control. This pipe (equalizing pipe) is trainlined and is charged during an independent or automatic brake application by the brake cylinder air from the lead locomotive. Either an independent or an automatic brake application can be released by depressing the independent brake valve handle. The depressed independent brake valve handle exhausts the air piloting the distributing valve of the lead unit, which in turn exhausts the air from the equalizing pipe and releases all brakes in the consist.

One method of making these two air brake equipments compatible MU-wise, was to trainline the 24-RL brake cylinder pipe. The shortcoming of this method was that the 24-RL unit always had to be in lead position.

It should also be noted that the 24-RL air brakes used independent brake trainline hoses having an "H" type coupling, whereas the 6-BL or 6-SL air brakes used independent trainline hoses having an "E" type coupling. Since these two types of coupling are not compatible, MU operation requires changing to like coupling.

There are three types of multiple unit control available with the No. 26-L Brake System:

A. The 2-pipe system. This involves an application and release pipe and an actuating pipe. The application and release pipe relays the independent brake valve pressure to the brake cylinder relay valves on all units in the consist. The actuating pipe provides a

quick release of the locomotive brakes resulting from an automatic service or emergency application.

When the independent brake valve handle is depressed on the lead unit, the pressure in the actuating pipe acts on all of the control valves in the consist to cause a quick release of the brake cylinder pressure. A dual-ported cutout cock or an MU-2-A valve is used to provide the correct porting when in Lead or Dead or Trail position. This equipment will MU with any other two-pipe system such as 24-RL, 6-BLC, 6-SLC or other two-pipe 26-L equipment, but not with one-pipe equipment such as 6-BL or 6-SL or 26-L one-pipe equipment.

B. The 1-pipe system. In this arrangement a single brake cylinder equalizing pipe runs throughout the consist, and the brake cylinder pressure on the trailing units is controlled from the pressure which is developed on the lead unit of the consist. The MU-2-A valve and F-1 selector provide the proper porting when in Lead or Dead, or Trail No. 6 or 26 position. MU break-in-two protection is also provided for in this combination. This equipment will MU with any other one-pipe system such as 6-BL, 6-SL, 26-L one-pipe, 26-L universal equipment, or 6-BLC, 6-SLC type No. 1, but not with two-pipe equipment such as 24-RL or 26-L two-pipe equipment.

C. The Universal System—Combines the features of both the single and two-pipe multiple unit brake cylinder pressure control. This equipment will MU with any other two-pipe system such as 24-RL, 6-BLC, 6-SLC universal 26-L, and two-pipe 26-L equipment, or one-pipe system such as 6-BL, 6-SL, 6-BLC, 6-SLC type No. 1, and 26-L one-pipe equipment.

Two-pipe 26-L locomotives may be equipped with either a dual-ported cutout cock or an MU-2-A valve.

Single pipe 26-L or universal 26-L equipped locomotives all have MU-2-A valves.

Figures 101 and 102 show typical dual ported cutout cock handle position nameplates.

Figure 103 shows the available MU-2-A escutcheon plates.

Figure 104 shows the various possible multiple unit combinations of 24-RL, 26-L and 6-BL or 6-SL brake equipment and proper positioning of the MU-2-A valve, dual-ported cutout cock, doubleheading cock, K2A rotair valve, or brake pipe cutout cock.

The following functions are also affected in MU operation and must be considered when foreign units are placed in the same consist:

Dynamic Brakes—There are two types of dynamic brake interlock available:

Type 1—The automatic service brake application *will* reapply on the locomotive when dynamic brake is released.

DUAL PORTED CUTOUT COCK NAME PLATE

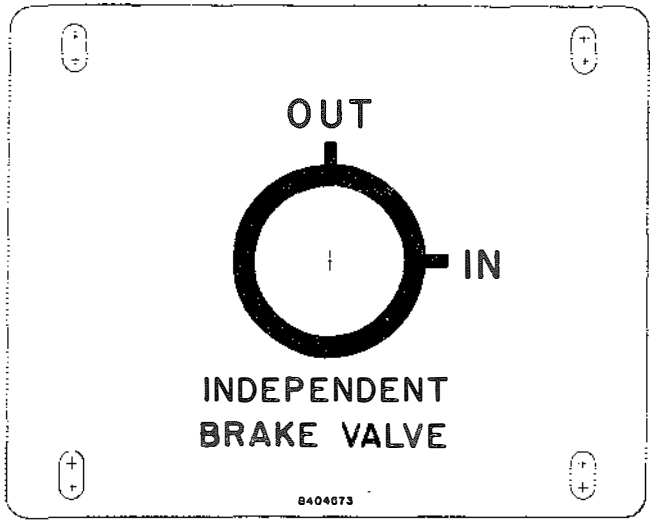


FIG. 101

DUAL PORTED CUTOUT COCK NAME PLATE

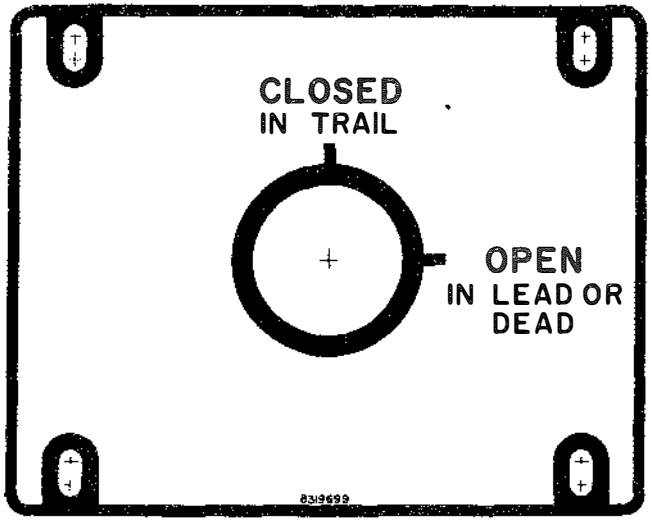


FIG. 102

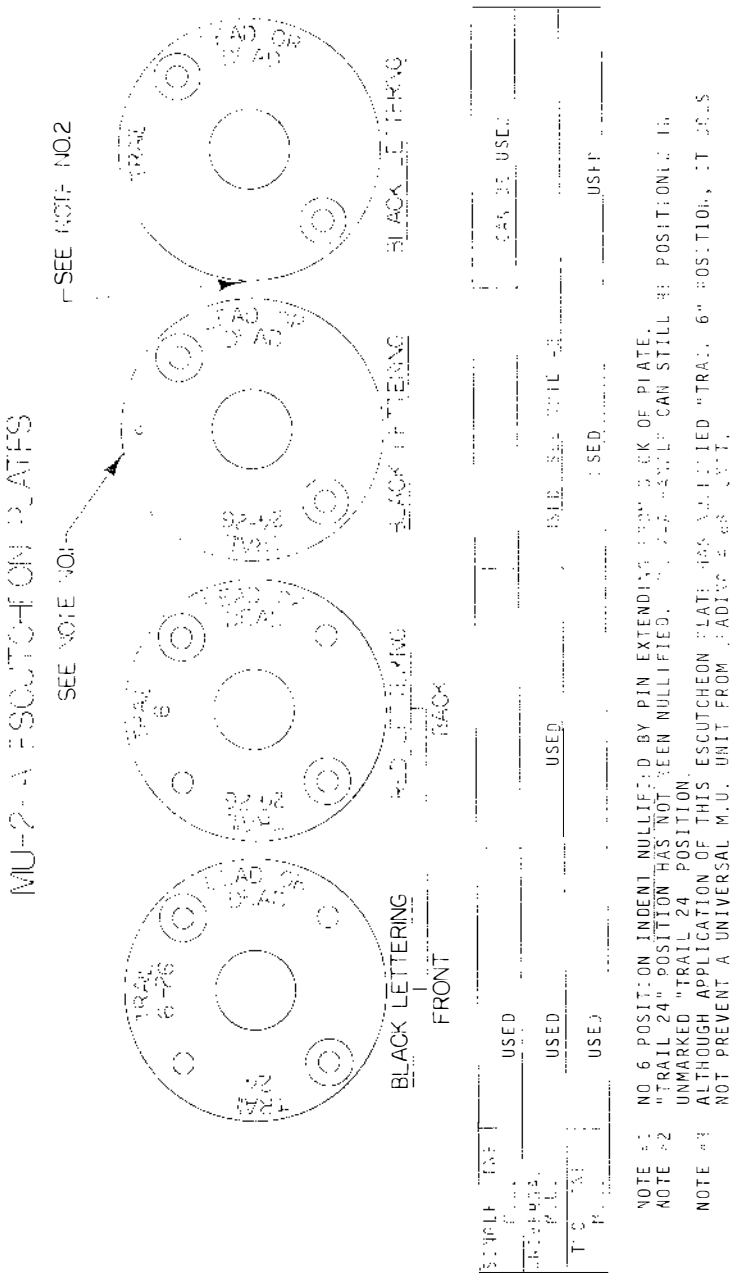
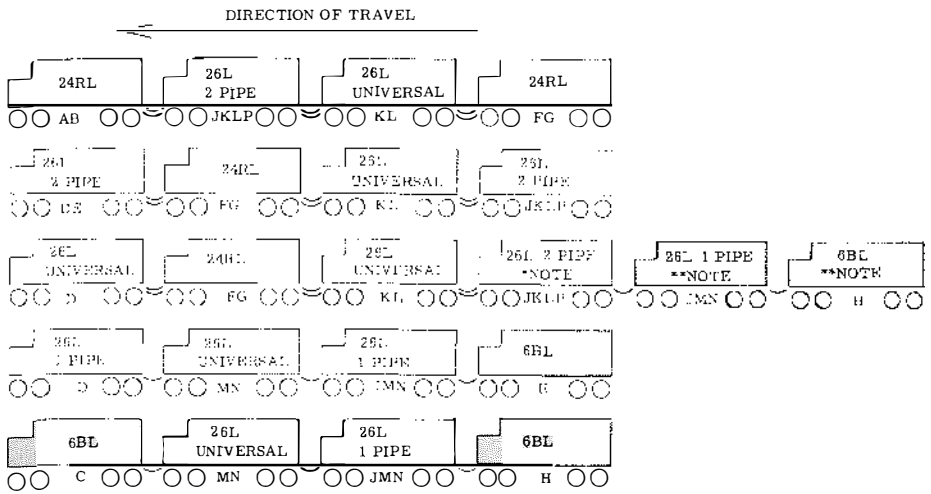


FIG. 103



TYPE BRAKE EQUIPMENT	TYPE VALVE	LEAD	TRAIL
24RL	BRAKE PIPE CUT-OUT COCK	A OPEN	F CLOSED
	K2A ROTAIR VALVE	B FRT OR PASS	G FRT LAP OR PASS LAP
6BL	DOUBLE HEADING COCK	C OPEN	H CLOSED
26L	MU2A VALVE	D LEAD OR DEAD	J TRAIL K TRAIL 24 L TRAIL 24-26 M TRAIL 6 N TRAIL 6-26
	DUAL PORTED CUT-OUT COCK	E OPEN	P CLOSED

FIG. 104 TYPES OF MULTIPLE UNIT CONSISTS

NOTE*: When a universal 26-L brake equipped locomotive and a 26-L two-pipe equipped locomotive having a brake cylinder relay other than 100% ratio, are operated together in MU, the two-pipe 26-L unit must always be in the lead. Placing the two-pipe 26-L unit in trail will result in increased or decreased brake cylinder pressure dependent upon the type of brake cylinder relay being used. For example, a two-pipe 26-L unit having a 1.6-16 relay valve would have 1.6 times as much automatic brake cylinder pressure as the leading universal 26-L equipped unit.

NOTE**: In this type of consist the 26-L (1 pipe) or 6-BL equipped locomotives must trail all 26-L (2 pipe) or 24-RL equipped locomotives in the consist.

NOTE: Wherever 6-BL is indicated 6-SL is connected in the same manner.

Type 2—The automatic service brake application *will not* reapply on the locomotive when dynamic brake is released.

Electric Sanding—There are two types of electric sanding control systems in use. Both types require the use of two trainline wires

Type 1—Fig. 105—The manual sanding employs the use of one trainline wire to provide the manual sanding function. The reverser interlocks on each unit control the direction of sanding. The second wire is used to provide an emergency sanding function to each unit. The reverser interlocks are bypassed and sanding occurs in both forward and reverse direction.

Type 2—Fig. 106—This system requires the use of two trainlined wires. One for forward sanding and the other for reverse sanding. These wires are controlled by a directional manual sand switch. Emergency sanding is provided by energization of both wires.

When E.M.D., G.E., and/or Alco units are operating in mixed consist it is important that the difference in individual dynamic brake retarding force be allowed for so as to avoid slack action.

E.M.D. and G.E. air compressor synchronization control are similar in that both types load when the trainline is energized. Alco units load when the trainline is de-energized.

Standardization of electric trainline is being investigated by the A.A.R. Until standardization does take place, it is necessary to continue the use of special jumpers.

All trainline hoses between units must be properly connected and cocks opened.

The engineman must observe that the main reservoir air pressure indicated on the gauge is normal for that class of service on the particular railroad before attempting to move the locomotive. Many locomotive units equipped with electro-magnetic switch gear can be moved before air pressure has developed on the locomotive, hence this precaution should be taken before attempting to move the locomotive.

Before moving the locomotive, make certain that the air brake pistons and the brake shoes apply and release on all units of the consist. Make certain that the independent brake cylinder, brake pipe and equalizing reservoir pressure are at the prescribed values for the intended service.

C. Handling the Locomotive Light

1. A running test of the locomotive air brakes should be made with both automatic and independent brake valve as soon as possible after departing from the engine terminal or after cutting off from the train.

TYPE I ELECTRIC SANDING

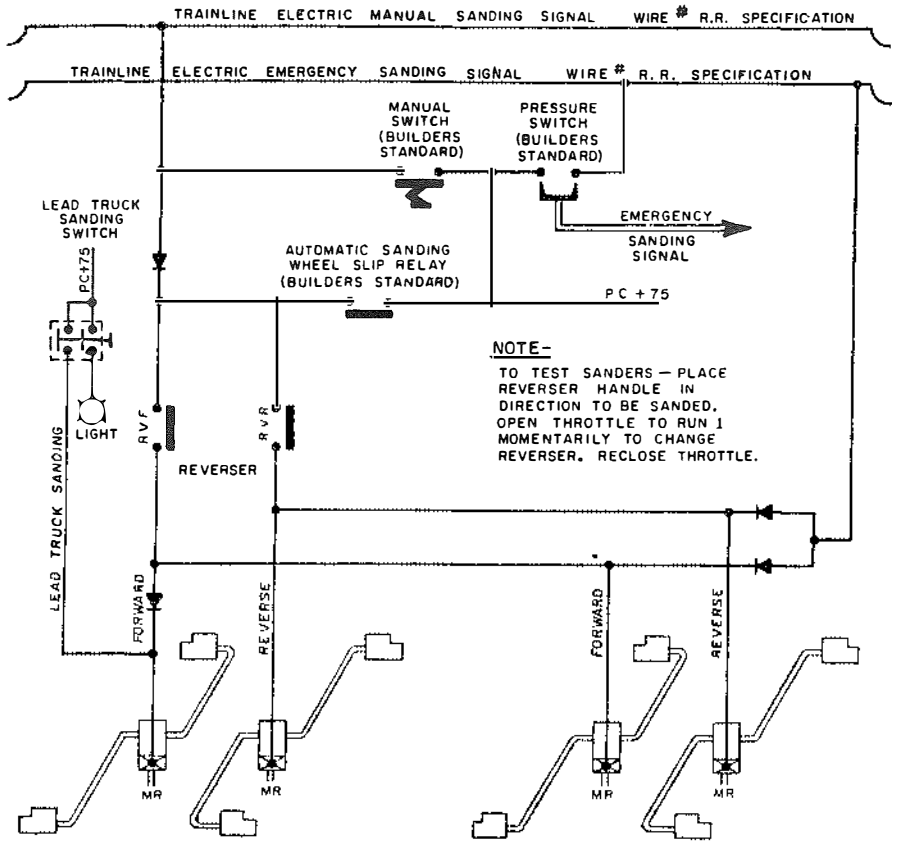
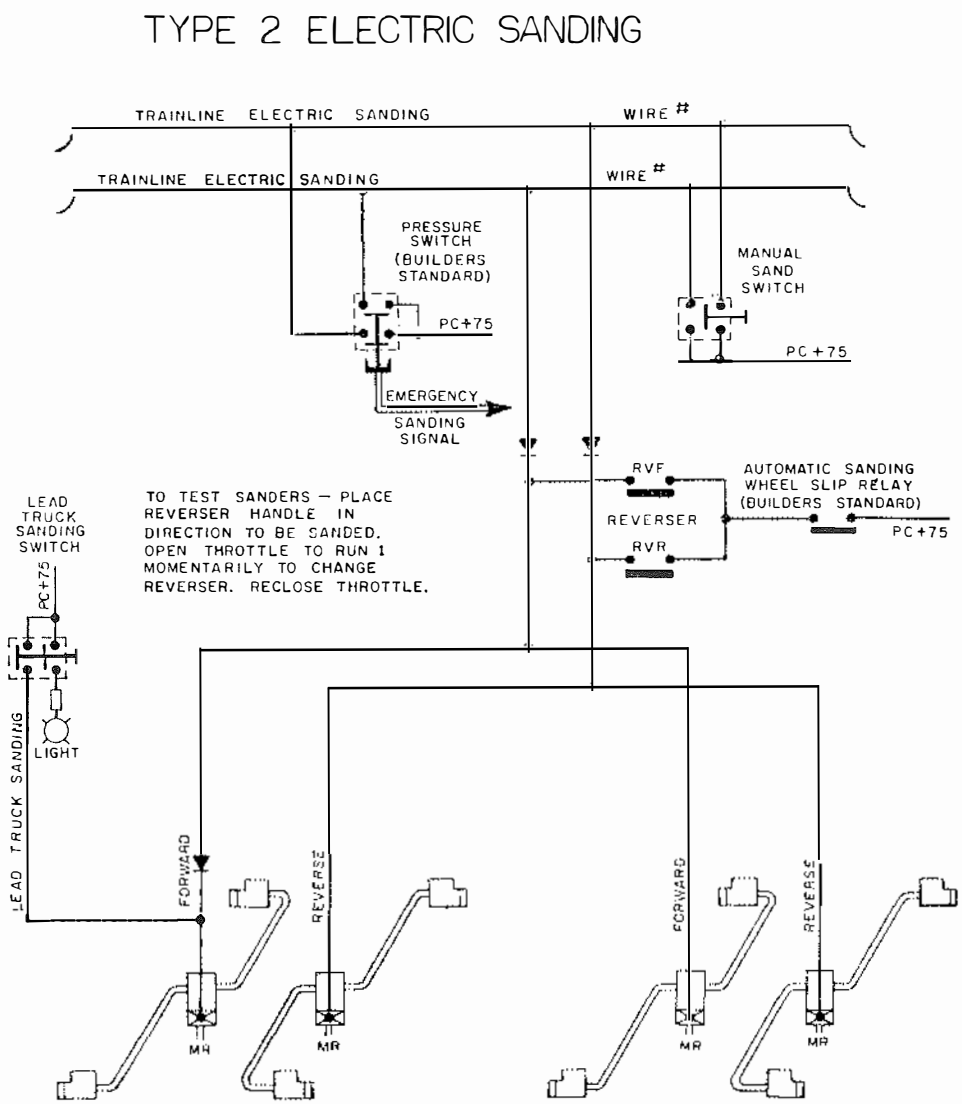


FIG. 105



TYPE 2 ELECTRIC SANDING

FIG. 106

2. If the locomotive is equipped with dynamic brake it is a good practice to make a running test of the dynamic, if conditions permit.
3. General good locomotive operating practice requires that the throttle is in idle before coming to a complete stop and also making no attempt be made to change the reverser position before the wheels have stopped rotating and the locomotive has come to rest.
4. When operating a light locomotive on a long descending grade, the same precautions should be observed as when handling a train on the same grade. If available, the dynamic brake should be used to control speed. However, if necessary to use the independent air brake, extreme care should be exercised to avoid excessive heat build-up in the brake shoes and wheels.

D. Preparation of Train for Road Movement

1. It should be ascertained that a proper coupling has been made to the first car of the train and that the brake pipe is connected and angle cocks are open. Caution must be exercised in opening the angle cocks to avoid an emergency application at this time, as this only wastes time and compressed air. If an emergency is initiated, PC action and emergency sanding will result on most locomotives.
2. It is often necessary to double over to pick up other sections of the train which have been made up on adjoining tracks. The same care in coupling to the train to assure a proper mechanical connection has been made and that an emergency air brake application is avoided, applies here as well.
3. Charging the Train Air Brake System
   a. Charging train from Road Locomotive: If the train is to be charged from the locomotive only and there is little or no air in the reservoirs of the cars, proper charging time must be allowed. On many railroads, it is permissible to speed up the diesel engines with generator field switch off and reverser in neutral to provide increased compressor capacity. The engineman should pay close attention to the main reservoir pressure gauge in the lead unit. When charging a so called "dry train", the air flow in the first few minutes will be very high. Beyond approximately 3 to 5 minutes, the air compressors at normal idling speed will probably be able to provide all the compressed air needed for the train. When reservoir gauge indicates normal cycl- in between cut-in and cut-out pressures, engine speed may be reduced accordingly.
   b. Train Pre-Charged by Yard Plant: In this case, the yard plant compressed air pressure should be approximately 15 psi less than the normal brake pipe pressure to be carried by the train. If the yard plant pressure is set too close to the brake pipe pressure setting of the locomotive, difficulty may be encountered in properly releasing the brakes on the train following the terminal test.
   c. Rear End or Intermediate Assist: These same precautions should

be observed when charging the train with a locomotive or yard plant assisting. In this case, it is a good practice to make sure that auxiliary pressure supply is at least 15 psi less than that of the controlling locomotive.

4. Train brake tests should be made according to the prescribed operating procedures. In making the brake pipe leakage test, a false leakage reading can be obtained if the timing of the leakage test is started immediately after the brake pipe exhaust closes. It is recommended that a waiting period of at least 30 seconds be used after the brake pipe exhaust ceases before beginning to time the brake pipe leakage. The purpose of the waiting period is to allow the brake pipe pressure to establish its true condition.
5. *Make certain adequate time is allowed for train brakes to release before attempting to start the train.*
6. If it is suspected the train is overcharged refer to Chapter III for methods of reducing the overcharge.

E. Starting the Train

1. The diesel-electric or electric locomotive is capable of exerting high-steady starting tractive effort. This starting tractive effort is equal to approximately ¼ of the locomotive weight. Multiple unit consists can produce excessively high total tractive forces if care is not exercised in their use by the engineman.

   For example: A 4-unit consist of 130-ton diesel-electric units can produce 250,000 lbs. or more pull on the train. Or a 4-unit consist of 190-ton diesel-electric can produce approximately 360,000 lbs. pull on the train.

   Many trains cannot withstand these forces without possible failure of couplers and draft gears. As a general rule, 250,000 lb. is about the maximum practical useable tractive effort with ordinary mixed train consists of interchange cars. Cars equipped with latest design high strength couplers and draft gears withstand higher forces but with other than "unit trains" it will be some years before enough cars are equipped to raise the practical maximum useable drawbar pull. Wait long enough to insure brakes are released on all the cars before attempting to start.

   Apply power slowly and steadily, and observe the load indicator. See Figures 107, 108, and 109 and table below:

(0-10 mph, 62:15 gear ratio, full field)

amps	4-motored unit	6-motored unit
400	15200 lb.	22800 lb.
600	26400 lb.	39600 lb.
800	38400 lb.	57600 lb.
1000	51600 lb.	77500 lb.
1200	64800 lb.	97200 lb.
1400	78400 lb.	117500 lb.

2. Effect of Slack

   Slack or "play" between cars is present to greater or lesser degree on all cars. Free slack or the mechanical free motion between two adjoining couplers can be as much as 1 inch.

   Conventional draft gears, to which the couplers are attached, act to absorb shock and impact. However, they have from 2-3 inch movement built in. Therefore, there is a sizable movement possible *within a train* between the front and rear ends.

Train Length	Free Slack	Draft Gear Movement	Total for Train
50 Cars	50 in.	250 in.	25 ft.
100 Cars	100 in.	500 in.	50 ft.
150 Cars	150 in.	750 in.	75 ft.
200 Cars	200 in.	1000 in.	100 ft.

Slack is a benefit in starting a train because it can allow starting cars individually, rather than all the cars at one time. However, do not take slack indiscriminately; it may not be necessary. Watch the Load Indicator and get the feel of the train. If the train will start without the Load Indicator getting too high, taking slack is not necessary.

Keep the locomotive speed slow and constant until the rear of the train is in motion. If the controlling unit is not equipped with a variable throttle response device, it may be necessary to keep some independent brake applied on the locomotive to aid in controlling locomotive speed. For example, if the locomotive is allowed to accelerate too rapidly, the standing cars in the train will be "jerked" from 0 to 4 mph. This "jerk" action may easily exceed the strength of draft-gear and couplers. Brakes applied on the rear cars can make this jerk situation more serious.

Certain ascending grade starting situations require special care in gathering slack. Under these conditions, good communication between the locomotive and caboose is extremely useful.

Where the greater portion of the train is on an ascending grade and it is necessary to take slack to start the train, the operation must be handled carefully to avoid harsh slack action or a roll-back of the train. During a slacking operation, the locomotive must be moved very slowly in both the backward and forward movement.

There are several proven methods for bunching and holding train slack on grades, such as:

(1) When communication is established, trainmen may be advised to set a sufficient number of hand brakes on the rear portion of the train. The engineman will then make a twelve (12) pound brake pipe reduction. Reverse the locomotive and move the throttle to position one

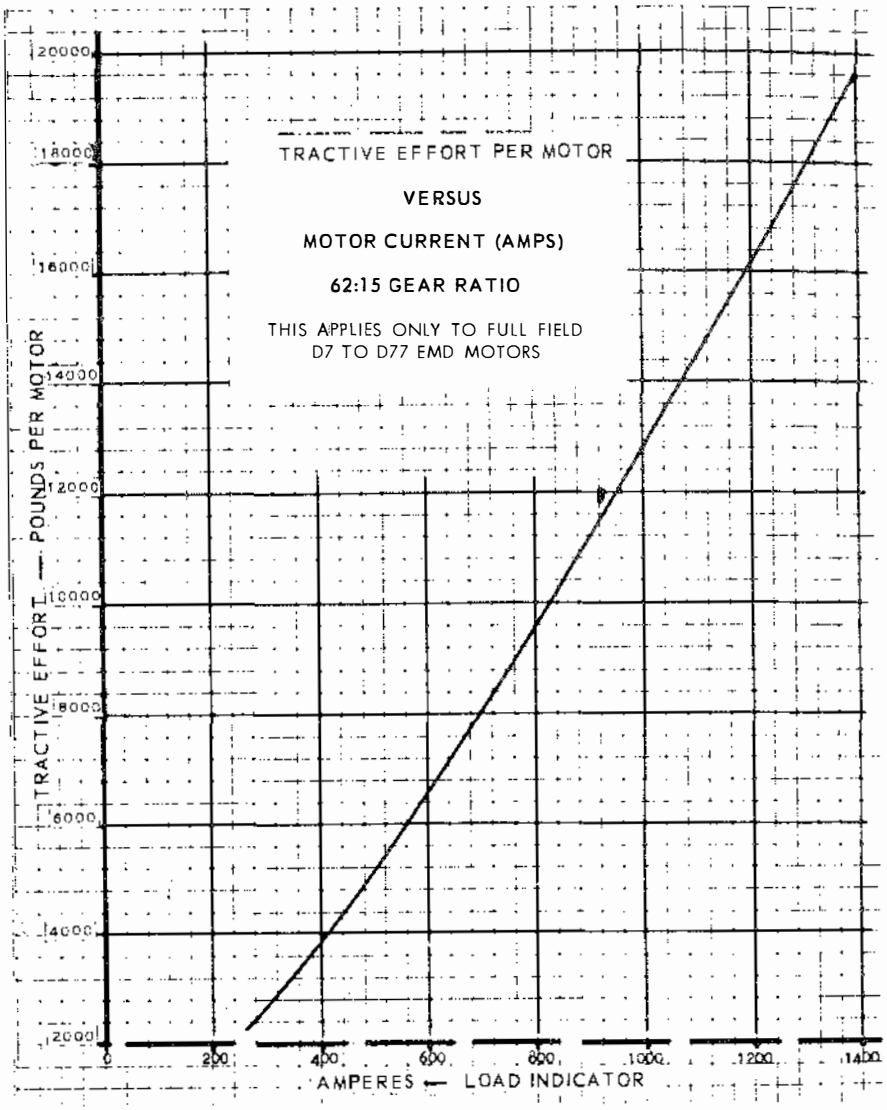


FIG. 107

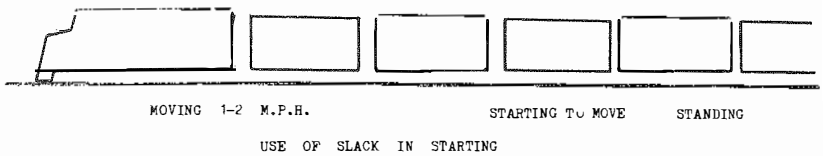


FIG. 108

and back to idle. Place automatic brake valve in running position and allow the locomotive and head portion of the train to slowly roll back, bunching the slack. Then place the reverse lever in forward position, open the throttle to a position required to slowly start the train while the rear brakes are releasing. The throttle should not be advanced to start the train while the amperage is increasing. When engineman sounds proceed signal (or communicates by other method) trainmen will start to release the hand brakes.

(2) When communication is available, the engineman may request trainman to place the caboose brake valve in No. 1 position, then start the slacking movement. Should the caboose start to move, trainman must increase brake application with the caboose valve, stopping the movement. After the stop is made, engineman will request the trainman to close the caboose valve, then make 12-pound brake pipe reduction, release brakes and start the train as outlined above. This method can only be used when the caboose valve is of the A-1 type which can be released without moving to full application position.

(3) When communication is not available between locomotive and rear of train this method may be used to delay the brake release on the rear portion of the train.

(a) Make brake pipe reduction sufficient to hold the train with respect to the degree of grade.

(b) Back gently into the train to bunch slack until the rear car moves. Continue the service reduction until the train stalls. (Use of pressure maintaining is highly desirable in this type of operation to insure the degree of application can be uniformly held on the train).

(c) Apply the independent brake fully before closing the throttle. Continue the service reduction to about 10 psi below the equalization pressure.

(d) Close the throttle.

(e) Position the reverser for forward movement.

(f) Release the automatic brake, open the throttle and move slowly, varying the independent brake as required to hold the speed low and steady.

Use good judgement and apply power "gradually" to start a train which is on a curve or curves. High starting tractive effort may pull a lightly loaded or empty car off of the tracks or out of the train, especially if the curvature is sharp. If an upgrade is involved, the situation can be more serious.

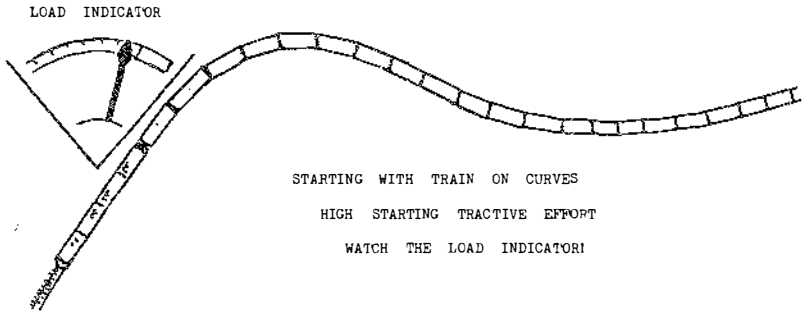


FIG. 109

If one or more of the locomotive units starts to slip or lurch intermittently while starting, *be careful with throttle handling.* It is better to close the throttle, take slack and start over again. Otherwise, the surges in tractive force due to one unit or another slipping may result in momentary excessive strains on couplers at some point back in the train. With the front part of the train tightly stretched, the effect of slipping, is like twanging an overly taut bow string to the point of snapping.

If the locomotive cannot move the train, do not let the amperage build up too high for damage can be done to the traction motor brushes and commutator bars, commonly called "stall burning".

Summarizing:

1. Know your railroad.
2. Know where your train is on the railroad.
3. Make sure a proper brake release is obtained.
4. Know where the train slack is and adjust if necessary.
5. Take slack carefully and only if required.
6. Use care in starting a stretched train.
7. Apply power gently and smoothly, one notch at a time.
8. Watch the load indicator.

F. Operating the Train

1. Low Speed Switching and Hump Operations
   a. When switching cars in a Hump Yard, the air brake systems on the cars are not normally charged and the locomotive brakes only are used to control the cut of cars. When necessary to stop under these conditions, care must be exercised to prevent wheel sliding on the locomotive. When operation requires a considerable amount of stopping and holding on the hump it may be desirable to charge the brake system on several cars adjacent to the locomotive to assist in holding the cut of cars. Care must be used in applying tractive power to push the train so that amperage does not build up too high. However, most locomotives regularly used in hump service have a special "hump control" which allows a high steady tractive effort to be exerted at very low speeds of ¼ to 2 mph.
   b. When pushing a heavy cut of cars onto loading and unloading docks the same precautions and approach to train handling apply as in hump operation. However, it may be necessary to stop cars at loading chutes, tipples or unloading pockets. If the cut of cars is not too long or heavy and the locomotive is equipped with 26-L or other maintaining brake valves, it may be practical to make a minimum brake pipe reduction and still move the train. Simply closing the throttle will produce a quick stop from low speeds of 1 to 3 mph.
   c. *Switching:* Handling cars in yard switching demands attention to the requirements of this type of service. Most switching involves handling cars which have had the air brake system drained, or the brake cylinder release valve actuated. Therefore, it is important to realize that the only power brakes may be on the locomotive. Do not attempt to handle more cars than can be safely stopped by the locomotive independent brake.
      Avoid jerking the cars into motion, because car equipment, lading and couplers may be damaged.
      When switching cars in or out of the head portion of freight trains, regulate brake pipe pressure to 5 psi below brake pipe pressure authorized for the train being switched. When handling cars to be placed in the rear portion of a freight train, adjust the brake pipe pressure to at least 10 psi below the brake pipe pressure authorized for the train.
   d. Many switching locomotives are equipped with a "fast start" function allowing better low speed acceleration when kicking cuts of cars. Road locomotives normally are equipped with a more gradual acceleration capability usually termed "slow start".
2. Back-Up Movements
   Care is required in handling throttle and brakes in order to avoid harsh slack action and damage to equipment and lading when making back-up

moves. Observe the following precautions when backing a train:

a. Allow sufficient time for train brakes to release before applying power.

b. Apply power gradually. Do not use any more power than actually required to smoothly start the train in motion. This is particularly important on multiple unit locomotives in order to avoid derailment or "buckling" of cars or locomotive units.

c. Do not attempt the back-up move by taking slack and then applying heavy or excessive power.

d. Give attention to indications that brakes are being applied from the rear, observing the brake pipe flow indicator (where used) and/or brake pipe and main reservoir gauges.

e. If there is any sudden drop in amperage or any unusual surge in amperage is noted, promptly apply the independent brake and close the throttle. This condition may have been the result of train buckling.

When stopping the train from a back up move, there are several points requiring attention in order to insure good handling:

a. If brakes are applied by the engineman, make a light brake pipe reduction while working power, holding the locomotive brakes released, independently. Continue to use power. After slack has adjusted, make further train brake pipe reductions if conditions require. Make these additional reductions in 2-3 psi steps. Avoid making any "heavy reductions" when backing up. Use only sufficient power, as speed reduces, to prevent the slack from running out. As train comes to rest, close the throttle and apply the independent brake promptly.

b. When brakes are to be applied from the "rear end" by means of the back-up valve or back-up hose, continue to use power lightly, if grade conditions require. Hold the locomotive brakes released with the independent until the stop is completed. Generally, power should be used when practical during a stop from a back-up move.

c. Automatic power reduction provides an infinitely variable load control below full load on the lead unit of the consist. This is useful when operating under heavy wheel slip conditions on a steep grade. Usually the lead unit will clean the rails for the trailing units, therefore, automatic power reduction makes it unnecessary to reduce the throttle on all units if only the lead unit is slipping.

d. When the back up hose is used to control the movement of freight cars on a back-up move, the trainmen must couple the back-up hose to the brake pipe at the leading end of the train during the move. To insure the brakes are operative and properly controllable from the back-up valve or hose, the following procedure is recommended:

The back-up hose or back-up valve provides a means for the application of brakes from the rear end of the train. Before attaching the back-up hose, the rear hose of the train must be blown out. After attaching and cutting in the back-up hose, make a sufficient discharge of air to insure the angle cock is open. For a service brake application, the valve should be opened slightly, yet fast enough to apply brakes gradually, increasing the valve opening until the desired holding force is obtained. The locomotive automatic brake valve must be in running position; therefore, the discharge of pressure at the rear of the train must be continuous to maintain the brake application. The back-up valve on cars so equipped should be used instead of a back-up hose.

G. Over-the-Road Operation

During the time that the train is being accelerated, work power steadily. Avoid quick throttle changes—"jockeying the throttle up and down". This can create snap or whip action in the train. Reduce throttle if a wheel slip indication persists or acceleration is too fast.

As speed increases beyond the starting rail adhesion limit, the tractive effort reduces in proportion to the increase of speed. This is because the traction horsepower is basically constant for any specific throttle position. Each throttle step is in reality a specific horsepower position. For example, with a 3000-horsepower locomotive unit.

Throttle—Run 1— 200 hp
Run 2— 390 hp
Run 3— 710 hp
Run 4—1085 hp
Run 5—1420 hp
Run 6—1830 hp
Run 7—2375 hp
Run 8—3000 hp

However, the train resistance increases steadily as the train speed increases. When the horsepower output of the locomotive equals the resistance horsepower of the train a power/speed balance is reached. Speed will not increase further unless more power is applied.

As the desired speed is approached, reduce throttle gradually until speed balances or holds steady. If necessary to hold a particular speed which will not balance at any particular throttle setting, the throttle position will have to be varied. Make throttle handle position changes slowly.

Avoid unnecessary "drifting" and then reapplying power when handling freight trains. The locomotive may "back into the train" while drifting which will tend to cause slack to bunch. This may not be sensed on the locomotive. When power is reapplied, slack will be pulled out and if this

happens too quickly, a jerk may be experienced and result in damage to lading or equipment.

Summarizing:

1. Plan all movements in advance to control train speed and slack.
2. Never allow the train to "control the engineman".

H. Decelerating the Train

1. Train resistance varies with the type of train, cars, bearings, track profile, curves and loadings; train resistance generally increases as train speed increases. Where sufficient distance is available and other conditions permit, speed reductions can be made by simply letting the train slow down due to its inherent resistance. The throttle should be slowly and gradually reduced to give the train slack time to adjust itself without surges and shocks. Generally, the locomotive will tend to "back into" the train and cause a natural bunching or roll-in of slack. However, if there are grade situations where the locomotive and head end slack may tend to remain stretched, use care in employing the independent or the dynamic brake. Do not apply it too rapidly or too heavily as severe run-in or slack may be experienced. For example if a train running at 35 mph with slack out, is subjected to a quick hard application of the independent or dynamic brake. In a short time the head end can be 5 to 10 mph slower than the rear end which, in effect is still running at 35 mph. Slack run-in and shock can be extremely severe.

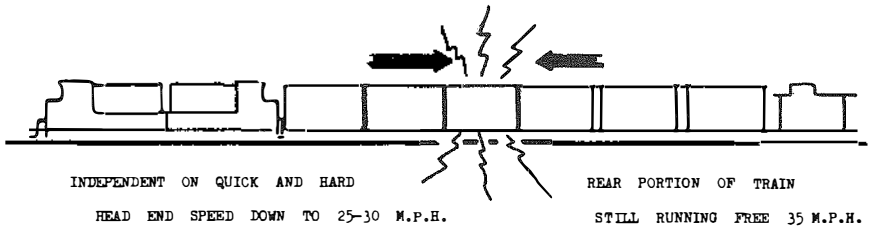


FIG. 110

2. The basic cause for slack action is that one portion of the train is running faster or slower than another, which is related to the following factors.
   a. Car resistance to movement can vary considerably in different parts of the train.
   b. Heavy cars tend to run ahead easier on down-grades and pull harder on up-grades than empty or lightly loaded cars.
   c. Curves create more resistance than does straight track.

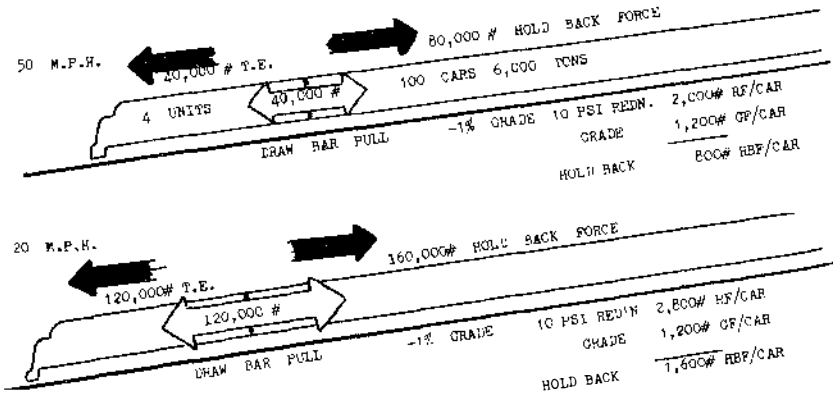


FIG. 111 BRAKING AGAINST POWER ON DOWNGRADE

   d. At lower speeds, roller-bearing cars tend to run more freely than plain-bearing equipped cars.
   e. The engineman should endeavor to learn the characteristics of the railroad and equipment in the train such as train length, number and position of loads and empties, tonnage, etc. This knowledge will assist him in proper use of power and brakes to adjust and control speed and slack.

3. Braking Against Power

   There are situations where braking against power can be used to obtain satisfactory speed reductions and train handling. However, it must be recognized that it is not always possible to keep every train stretched at all times. Severe strains on couplers and draft gears can result if proper attention is not given to the load indicator as speed reduces.

   When the train brakes are applied for a slow-down, the minimum speed and grade conditions must be such that a running release can be satisfactorily accomplished. When braking to control slack, do not permit the locomotive brake to apply. Make no throttle change if in full throttle position. If in other than full throttle, and conditions permit, advance throttle to increase power during the time brake pipe is exhausting. Throttle should be reduced as speed decreases to prevent tractive effort from building up too high, which may lead to train separation.

The attempt to stretch-brake or to power-brake on descending grades for slowdowns or stops can lead to excessive drawbar stress in the front part of the train.

In Fig. 111, a medium weight train of 6000 tons is braked with a service application somewhat heavier than the 8-psi train brake pipe reduction required to balance the grade and power is used. As speed reduces, the car brake retarding force increases and more power must be used to counterbalance this in order to maintain the desired rate of speed reduction. As can be seen the 40,000-lb drawbar pull at 50 mph increases to 120,000 lb at 20 mph. If the speed is further reduced cars will hold back harder and the drawbar pull will have to be increased even more. Excessive wear of brake shoes and wheel heating may result if the application is held for a long time.

In Fig. 112, a long, medium weight train is braked against power for a 60 to 20 mph slowdown on relatively level track. Note, that even with a minimum brake pipe reduction of 7 psi it is necessary to work considerable power to simply keep the speed steady as the brake release speed is approached.

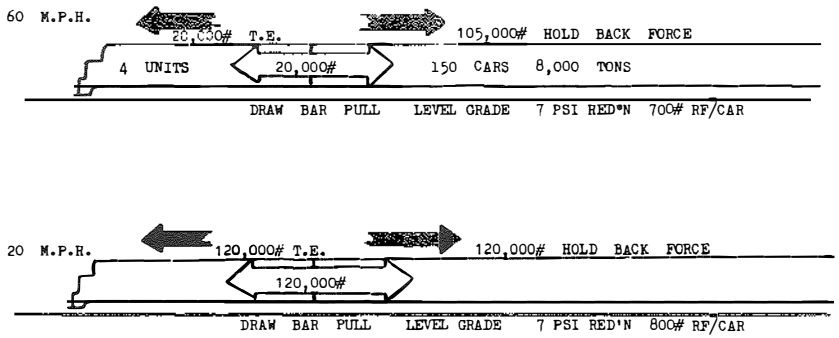
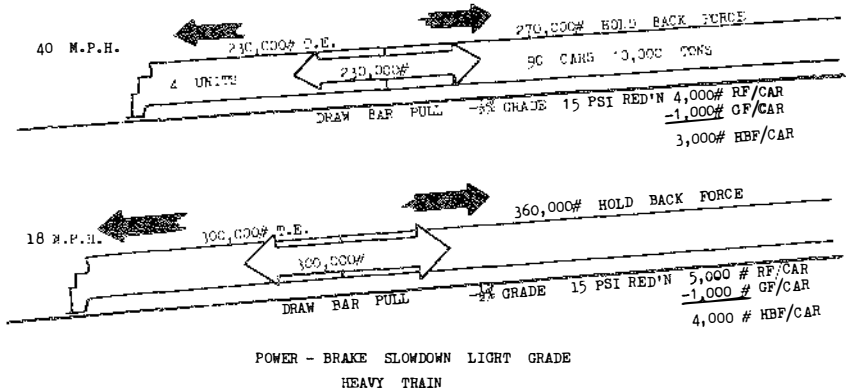


FIG. 112 POWER-BRAKE SLOWDOWN ON LEVEL TRACK

Fig. 113 illustrates an attempt to reduce speed slowly by power-braking a heavy train on a descending grade approaching a point where either a stop or proceed signal may be obtained. Because of the grade, a fairly heavy brake pipe reduction is required to "over-balance" the grade and power is worked to give the desired rate of speed reduction. At high speeds, power is required but the drawbar pull is high, approximately 140,000 lbs.

In order to prevent stalling, the throttle must be left in position or advanced and amperage allowed to increase because the brakes become more effective as speed reduces. Examine the situation when speed has reduced to, say, 18 mph:



POWER - BRAKE SLOWDOWN LIGHT GRADE
HEAVY TRAIN

FIG. E-8

FIG. 113 POWER-BRAKE SLOWDOWN LIGHT GRADE HEAVY TRAIN

In this case, the head-end drawbar pull is around 300,000 lb. It should be obvious that a lighter brake application and less throttle would have avoided excessive drawbar pull.

The above example is the same as pulling an overbraked train down a long grade. Good judgement must be used in order to avoid overworking brake shoes and wheels. Observe the train frequently for any signs of excessive braking.

In any grade braking situation remember:

1. Cars will normally "bunch" on a descending grade.
2. Cars will normally "stretch" on an ascending grade.
3. Only the front portion of the train will be affected by power or "stretch" throttle usage.
4. Drawbar forces are the result of both a pulling throttle and the retarding force of the cars.

4. Dynamic Braking

The dynamic brake can often be used to advantage in slowdowns and stops. As pointed out previously, the dynamic brake concentrates the retarding force at the head end of the train. Therefore, care must be used to prevent the development of excessive retarding force in the front portion of the train.

All EMD locomotives (built after March 1971) are equipped with a 5 to 7-second delay of dynamic brake. The delay is started when the throttle is placed in idle and affects only the unit equipped, and not the other unequipped units which may be in the locomotive consist. The engineman must still be instructed to wait approximately 10 seconds between idle and dynamic brake.

With multiple unit consist it is possible to create sufficient retarding force with the dynamic brake to cause extremely high compressive force in the train. Particular care must be taken on curves, turnouts, and switches. This is very important on a downgrade. When changing from throttle position to dynamic brake do not attempt to do this quickly, or harsh slack action may result in the train. Reduce throttle preferably one step at a time, pausing a few seconds between steps. A good "rule of thumb" is to wait at least 2 to 3 seconds before reducing throttle to the next lower position. This will give 15 to 20 seconds for train slack adjustment to start.

In changing selector lever from power to dynamic brake, wait at least 10 seconds in IDLE before going to B position. There will be a slight amount of braking effort as shown on the load indicating meter. Depending on the road, the various conditions of grade, curvature and type of train facilitates the increase of dynamic brake slowly to insure easy final bunching of the slack. When slack is bunched, the throttle can be regulated as desired. Give attention to the brake warning light, reducing the amperage if the light stays on more than a few seconds. The dynamic brake and locomotive air brake must not be used at the same time except when:

a. Changing from dynamic to air braking during stopping.

b. Starting a train on a heavy descending grade.

On certain later design locomotives with extended range dynamic brake, maximum dynamic braking force can be maintained to about 6 mph. From 6 mph to zero speed, the dynamic brake force reduces rapidly to zero.

When the dynamic brake is used entirely for controlling the speed of a train and the train has empties or light loads on the head end and heavy loads on the rear end, good judgement must be exercised to avoid maximum dynamic brake while head-end cars are passing through a crossover, turnout or around sharp curves. It is particularly important that slack is not allowed to bunch harshly during these operational conditions.

When handling a tonnage train on a descending grade where the dynamic brake will not properly control the speed of the train, the air brake should be used to an extent which will allow the dynamic brake to be reduced to a value where it will be flexible enough to control the changes made in speed due to physical characteristics of the road. Where practical, it is important to plan the movement well in advance to avoid maximum dynamic brake while head-end cars are passing through a crossover, turnout or around sharp curves.

There are two approaches to the use of dynamic and train air brakes. When conditions of speed, grade, curvature, and train permit, the dynamic brake can be applied first to bunch train slack, and then followed with a suitable automatic service application. The other method is to make a service train brake application first and then apply the dynamic brake.

When train brakes are used in conjunction with the dynamic brake, the air brakes should be started with a minimum brake pipe reduction and followed by additional reductions necessary to properly control the train speed. The independent brake valve handle must be depressed frequently enough to insure that air brakes are released on locomotive. If the train brakes are to be released while the train is moving, leave the dynamic brake fully applied until sufficient time has been allowed for brakes to be released on the train. After the train brakes have been released, continue to use the dynamic brakes as needed. If not needed, move the selector lever slowly to "B" position and then to "OFF" position, stopping in each position not less than 5 seconds and then move to position "One". When making a stop, as the speed reduces to the range where the dynamic brake effectiveness is rapidly reducing, the independent brake should be judiciously employed to keep the locomotive holding back against the train.

6. Service Applications of Automatic Train Brake

In using the automatic service brake for slowdowns and stops, the best train slack control is obtained when a split reduction is made. Although conditions vary from place to place, a good rule of thumb is to make a minimum (approximately 7 psi) equalizing reservoir reduction; after approximately 20 seconds continue to the desired total amount. The initial light reduction gives train slack a chance to easily adjust. Since the automatic brake applies serially from front to rear, on long trains, head-end cars will have developed higher brake cylinder pressure before rear cars have very much pressure. The natural effect of this is to cause slack to close.

When a train brake application is made at low speeds to stop a freight train, the application should be made so that brake pipe pressure will

still be exhausting from the automatic brake valve as the train comes to rest. Make sufficient total brake pipe reduction to insure subsequent release of all cars in the train.

Brake pipe exhaust takes time and the longer the train, the longer the exhaust time. Brake pipe exhaust time also depends on the relative amount of brake pipe leakage. Another factor is the number of cars in the train equipped with quick service and/or A-1 reduction relay valves. As explained in Sections II and III, the quick service valve or quick service portion of the A-1 reduction relay valve operates to make a local reduction of brake pipe pressure each time a service reduction is made. For example, normal brake pipe exhaust times would be as follows:

Approximate Brake Pipe Exhaust Time (70 psi B.P.)

Train Length	Minimum Leakage		Max. Leakage 5 psi/min	
50 foot Cars	10 psi B.P. Reduction	20 psi B.P. Reduction	10 psi B.P. Reduction	20 psi B.P. Reduction
50	40 sec	55 sec	5 sec	40 sec
100	1 min 20 sec	1 min 50 sec	15 sec	1 min
150	1 min 50 sec	3 min 40 sec	25 sec	1 min 40 sec
200	2 min 30 sec	5 min 50 sec	40 sec	2 min 30 sec

NOTE:

Variations can be expected depending on any specific train, brake pipe leakage, number of long cars, weather conditions, etc.

7. Stopping on Level or Slight Ascending Grades
When a stop is to be made on level or light descending grade territory and train speed is low enough so that full use of automatic train brake is not required, the following procedure can be employed:

a. Reduce throttle to idle gradually and allow natural resistance to slow train.

b. When nearing a point of stop, bunch the slack gradually with the independent brake, being careful not to slide the locomotive wheels. It is a good practice to use sand.

c. With a fairly heavy train, a heavy independent brake application may be necessary. Watch carefully that high braking heat on shoes and wheels is not developed.

d. Stop may be completed with automatic service application if necessary or desirable to prevent roll-back of train slack.

8. Stopping on Heavy Ascending Grades
Reduce throttle one notch at a time until train speed is approximately 5 mph. Close the throttle at about 3 mph and use sand while making a 15-psi train brake pipe reduction. Hold the locomotive brakes released until the train stops. When the train stops, close the sanders and apply the independent fully.

9. Emergency Brake Stops

a. Brake valve emergency
Emergency brake application should be used only in case it is necessary to obtain the shortest possible stop. If such a situation arises, quickly move the automatic brake valve handle to emergency position. Leave the automatic brake valve handle valve in emergency position until the train stops.

After making an emergency brake application, close the throttle and start sand running in case the locomotive is not equipped with automatic emergency sanding.
Continue use of sand by manual sanding, if necessary until locomotive stops.

It is important to prevent wheel sliding if at all possible.

1. A sliding wheel will not produce as short a stop as a rolling wheel which is braked as hard as rail adhesion will permit.

2. Obviously, the second reason is to prevent possible damage to wheels, track, gears, motors and other components which often result from flat spots or built-up tread.

b. Locomotives are equipped with additional 1¼ inch emergency brake valves usually located adjacent to exit doors or on the opposite side of the cab from the engineman's station. These are only to be used in an emergency situation. Under no circumstances should an attempt be made to make a brake pipe reduction other than emergency with the 1¼ inch emergency brake valve. This will interfere with control of train brakes by means of the engineer's automatic brake valve and may result in an undesired release of an automatic service application on the train.

c. If an emergency brake application originates from the train other than on the controlling locomotive, close the throttle and move the automatic brake valve handle to a position to cut off brake pipe charging. If the locomotive is not equipped with automatic sanding in emergency, open the manual sanders and leave them on until the train stops.

d. If the dynamic brake is on when the emergency application occurs, and the locomotive does not have dynamic brake interlock, care must be used in controlling the locomotive brake cylinder pressure by

means of the independent brake valve in order to prevent wheel sliding. If the locomotive has dynamic interlock and an emergency brake application originates in the train a light independent brake application will control the locomotive between the time the dynamic interlock releases the dynamic brake and the locomotive brake cylinder pressure begins to develop from the emergency brake application in the train.

e. When a train is stopped by an emergency brake application originating from a source other than the automatic brake valve, the handle may be placed in release position after the train has stopped and the vent valves have closed. This will provide a source of air flow into the brake pipe to assist trainmen in locating a burst hose, broken pipe or severe pipe leak, or a train separation.

f. Always inspect all locomotive wheels for flat spots after the train has stopped from any emergency brake application. Follow railroad handling practices in case any flat spots are found.

g. After the train is again started, move slowly for a sufficient distance for members of the crew to visually inspect the train and board safely. Engineman and trainmen should pay particular attention to any evidence of stuck brakes, dragging brake rigging or any other unsatisfactory equipment conditions.

10. Applying Brakes From the Rear End

Conductor valves and back up valves are only for the purpose of stopping trains, and must not be used to apply train brakes in an attempt to control slack. Do not use these unnecessarily as they may cause a light service application from which stuck brakes may result, or may cause an undesired release of a locomotive initiated service application.

Where the caboose is equipped with the "A" type caboose valve, it should be used to make all service applications necessary to initiate from the rear.

Always keep the "A" type caboose valve handle in closed or "lap" position, when not in use.

Service application: Move handle to the right to notch #2. Leave the handle in this position until the brake pipe gauge hand stops falling. Note: After a brake pipe reduction has been initiated, never return caboose valve handle to "lap" until after the train stops. Some railroads prefer that the caboose valve be held in each position for prescribed lengths of time.

If this brake pipe reduction is insufficient, move handle to notch #3 and leave the handle there until brake pipe gauge hand stops falling. If this is still insufficient to stop the train, use notch #4 or notch #5. Never advance the handle to the next position while the brake pipe gauge hand is still falling, except to make an emergency application.

After the train stops, close the caboose valve, moving the caboose valve handle to extreme left. The engineman should be alert for indications of brakes being applied from the rear, such as:

1. Increased air flow through the automatic brake valve into the brake pipe—Main reservoir gauge changing rapidly, compressors loading more frequently, etc.
2. If the locomotive is equipped with a "B" type flow indicator, the reading will increase rapidly and may light the indicator lamp.
3. Speed may reduce abnormally and amperage, if the locomotive is under power, may also increase.
4. When an application from the rear is detected, the engineman should make a minimum brake pipe reduction of 6 to 8 psi and wait until the brake pipe pressure "settles". Reduce power gradually, making further 2 to 3 psi brake pipe reductions if necessary, until the train stops. When about 200 ft. from the stopping point, open the sanders, close the throttle and apply the independent brake. Make final brake pipe reduction so the exhaust is blowing when train comes to rest.

Emergency application: To stop the train in the shortest possible distance, quickly move the "A" type caboose valve handle to extreme right or "APP" position and leave it there until train stops.

I. Grade Operations

1. Operating freight trains down grades of any significant length, requires observance of the following:

a. Balancing the grade, or holding speed steady at safe and practical values.

b. Maintaining ample safety margin, or keeping speed to a value which will allow stopping the train anywhere on the grade within signal spacing or other prescribed limitations.

In order to hold speed steady on a downgrade, the force of gravity must be balanced by the sum of train resistance and brake retarding force. The heavier the grade, the lower the effect of train resistance; and the more brake must be used. Obviously, train resistance will vary with the type of cars, train make-up, and train length and weather. On heavier grades, the majority of the grade retarding force comes from the locomotive dynamic brake and the train air brake. The following conditions apply:

a. The amount of train brake retarding force used to balance the grade normally should not exceed one half (½) of the normal full service train brake available if dynamic brake and pressure maintaining are operative.

b. If pressure maintaining is available but dynamic brake is not operative, the amount of the brake required to balance the grade should not exceed 1/3 of the normal full service available.

c. With neither dynamic brake nor pressure maintaining available, cycling manipulation and use of retainers would probably be required. In this case, the train brakes are alternately applied and released. In order to insure holding an adequate reserve of pressure for stopping, the amount of train brake to balance the grade should not be more than approximately ¼ of the normal full service brake retarding force available.

2. On a grade, gravity acts on each ton of train weight with a force of 20 lb for each per cent grade as shown below:

Per Cent Grade	Down Grade Force of Gravity
1%	20 lb per ton
2%	40 lb per ton
3%	60 lb per ton

The brake retarding force required to balance the down grade gravitation force is the force of gravity less the car or train resistance. In the following examples, assume resistance is equal to approximately 4 lb per ton at speeds of 15 to 30 mph. Obviously, the heavier the car, the more brake retarding force is needed. However, the difference of a few tons in car weight requires considerably more braking. This is illustrated on the tabulation below and Figure 114. It is important for enginemen and trainmen to have an understanding of this.

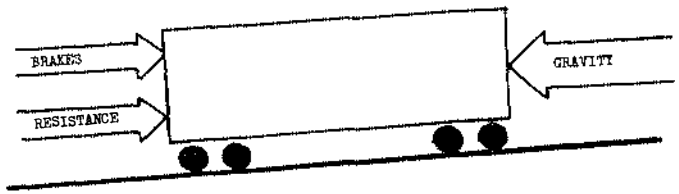


FIG. 114 BALANCING A GRADE

Train With Cars of 80 Tons Average Weight

Descending Grade Per Cent	Gravity Force	Resistance Force*	Required Brake Retarding Force	Approximate Brake Pipe Reduction
1%	1600 lb	320 lb	1280 lb	6 psi
1½%	2400 lb	320 lb	2080 lb	8 psi
2%	3200 lb	320 lb	2880 lb	10 psi
2½%	4000 lb	320 lb	3680 lb	12 psi
3%	4800 lb	320 lb	4480 lb	14 psi

Train With Cars of 100 Tons Average Weight

Descending Grade Per Cent	Gravity Force	Resistance Force	Required Brake Retarding Force	Approximate Brake Pipe Reduction
1%	2000 lb	400 lb	1600 lb	7 psi
1½%	3000 lb	400 lb	2600 lb	10 psi
2%	4000 lb	400 lb	3600 lb	12 psi
2½%	5000 lb	400 lb	4600 lb	14 psi
3%	6000 lb	400 lb	5600 lb	16 psi

Note: If curvature is particularly heavy, train resistance will increase and somewhat less brake will be required.

3. While a difference of 2 psi in brake pipe reduction to balance the grade may not seem too significant, it means quite a bit in stopping ability on the grade. A normal stop on the grade should always be available with the service brake. However, balancing the grade has used up a portion of the service brake. Therefore, a service stop on the grade will be similar to a stop on level territory with a partial service application. For example, if descending a 2% grade with a train of 80-ton cars (80 tons per operative brake) employing a 10-psi reduction to balance and using 70-psi brake pipe pressure:

The 2% grade stop would be similar to a level stop using a 10-psi reduction. If using a 90-psi brake pipe pressure, the 2% grade stop would be similar to a level stop using a 14-psi brake pipe reduction Therefore, a considerably shorter stop will result with the higher brake pipe pressure. It is common practice to carry higher brake pipe pressure in grade braking territory because of the increased margin of stopping ability. See Figure 116.

4. Components of the brake system including brake shoe and wheel have practical limits on the work they can be subjected to, or the braking horsepower they can dissipate. The practical limit is that which will give satisfactory performance of brake shoe and wheel down the complete grade with ample margin for stopping anywhere on the grade.

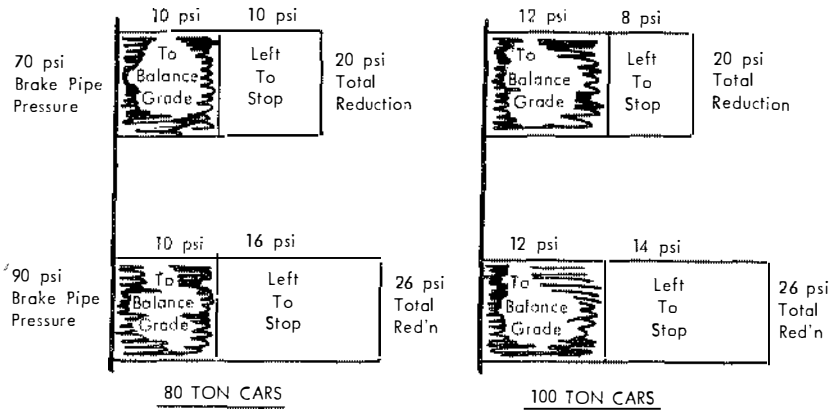


FIG. 116 EFFECT OF BRAKE PIPE PRESSURE ON GRADE BALANCING AND STOPPING

a. Braking horsepower varies directly with speed. For example, if a grade is descended at 30 mph instead of 15 mph, twice as much braking horsepower is required, even though the force of gravity on the train is the same.

b. The braking horsepower required varies directly with the weight of the train. An 8000-ton train takes twice as much braking horsepower as a 4000-ton train. If conditions permit, the lighter train can descend the grade at higher speed and still stay within practical limits of brake shoe and wheel performance. The braking horsepower required is provided by the combination of train air brake horsepower plus dynamic brake horsepower, if available (see section on dynamic brake for more complete information). If dynamic brake is available, it is obvious that the train air brakes do not have to be worked as hard. Higher speeds may be permitted under these conditions. In the opposite case, if dynamic is not available, it is only practical common sense to run under more conservative conditions at lower speeds.

c. Practical limits of continuous braking (work transferred from car brake shoes to car wheels) is in range of 20-25 hp for the 33 in.

freight car wheel. Larger wheels can take somewhat more horsepower, generally in proportion to the square of the diameter. Brake shoes are capable of performing satisfactorily within these ranges; however, shoes will wear at a faster rate with higher braking horsepower demand.

d. The effect of high gross car weights on the braking demand per car wheel is important. For example, on a train of 73 cars each weighing 110 tons, or total of 8030 tons, there would be 584 car wheels, not including locomotive or caboose to share the train air brake work load. This might be compared with a train of 146 cars of 55 tons average gross weight totaling 8030 tons as above, but with 1168 wheels to share the train brake work load. Obviously, a greater work load is imposed on wheels and brake shoes with trains of fewer and heavier cars.

5. Cycling brake manipulation: In the event that neither dynamic brake nor pressure maintaining is available, it will be necessary to descend the grade, using cycling manipulation and retainers set up. It is assumed that the required grade balancing brake application is heavier than that obtained with a minimum 6-8 psi brake pipe reduction. At heavier reductions, the brake cylinder pressure even with retainers, may reduce due to minor leakage if on the grade for a considerable period of time. Since the leakage rate varies from car to car, with some cars having very little leakage, compensating for this simply by increasing the brake reduction from time to time, would result in some cars having little brake cylinder pressure and others very high pressure. The brake shoes and wheels on the "low leakage" or "tight" cars may have excessive heat and wear. Therefore, it has proven to be more practical to release and reapply the train brakes from time to time. Hence, the term "cycling" implies that the speed will vary within limits because brakes are alternately applied and released.

a. Cycling manipulation and use of retainers go hand in hand. Retainers should be set up on a sufficient number of cars so they will hold just about enough brake cylinder pressure to balance the grade.

b. General practice is to make the initial brake pipe reduction somewhat heavier than that required to balance the grade, probably 9-12 psi, which is sufficient to fill brake cylinder to 20 psi or more. Timing of the start of this application is important as the train goes over the crest of the grade. The initial application should be started at a point that will prevent speed from becoming excessive as the train moves onto the grade and before the application becomes effective on the whole train. There is no substitute for good judgment and experience. It is better to approach the crest of the grade at a somewhat lower speed than authorized for the train, making the initial application a little on the light side in order to get the feel of the train as it comes over the crest, and then add to it if the train

seems to require additional retardation. Hold the initial application so that the speed reduces under the average speed required. Then release the brakes. Retainers should hold the increase in speed during the release to a slow rate which will allow the brake valve handle to remain in release position at least 45 seconds and preferably longer.

Start the next application at a speed which will allow brakes to become fully effective before excessive speed is reached. However, since the brake system will not have had time to recharge completely, it will be necessary for the engineman to compensate for this in making the second and all succeeding reductions. Keep track of the brake pipe and equalizing reservoir gages during the release. When the next application is needed, note carefully the brake pipe pressure which may be less than equalizing reservoir (say 76 psi B.P., 80 psi ER). For the succeeding application, subtract the desired reduction from that existing brake pipe pressure and reduce the equalizing reservoir to this value (76—12=64 psi). Another method is to measure the equalizing reservoir pressure reduction from the moment the Service exhaust starts to blow. These methods will produce the desired brake pipe reductions. The cars in the train respond only to the actual (net) brake pipe and reservoir pressure changes effective at that point in the train.

Long periods of "short cycling" brake operation usually result in slight but steady lowering of minimum car reservoir pressures.

Frequent observations of the train must be made while moving down grade. Pay particular attention to signs of excessive braking heating when using a cycling manipulation. Retainers will develop higher brake cylinder pressures on the head end than those toward the rear. Therefore, the head end cars will do considerably more braking work. Follow local rules in regard to cooling stops and train inspection. Follow local rules regarding stopping on grades. General good practice is to stop at a point where the locomotive independent brake will hold the train thus allowing the train brake system to be fully recharged.

6. Pressure Maintaining

With pressure maintaining, brake pipe pressure is maintained against brake pipe leakage to the level of the pressure in the equalizing reservoir. The normal or natural brake pipe gradient, or "taper" from front to rear will be maintained during service applications.

Pressure maintaining is a basic feature of the 26-L equipment and is an optional feature, although widely applied, on 24-RL. Train brake release action is faster and more positive with pressure maintaining.

a. A word of caution: If brake pipe and system leakage is excessive, the pressure maintaining feature may be overtaxed and unsatisfactory train brake operation may result.

b. When making an automatic train brake pipe reduction, the amount of reduction effective on the train should be measured from the brake pipe pressure at which the brake pipe exhaust starts. This is particularly important if an application is required before the train brakes are fully released and recharged.

c. If a very light reduction is made, much less than about 6 psi, the quick service activity of the car brakes may reduce the brake pipe pressure below that of the equalizing reservoir. This will cause the maintaining feature to attempt to increase the brake pipe pressure by feeding air into the brake pipe. Therefore, some or all of the car brakes may release.

d. Pay close attention to the equalizing reservoir pressure when the application is to be held for any length of time. With 24-RL equipment a small increase in equalizing reservoir pressure may occur. This is due to the natural temperature change effect during the reduction of equalizing reservoir pressure. As the temperature equalizes with ambient, the increase in air temperature in the fixed volume of equalizing reservoir may cause a sufficient rise in pressure to cause the maintaining feature to start to raise brake pipe pressure accordingly. This will probably cause brakes to release. If equalizing reservoir pressure starts to increase, make careful but slight reductions to compensate. This is termed "shaving".

e. On 26-L equipment the equalizing reservoir pressure is controlled by the self-lapping regulating valve which will automatically compensate for pressure temperature changes.

f. Attention to the main reservoir pressure and load-unload cycle of the compressors will indicate the relative amount of air flow into the brake pipe, if the locomotive is not equipped with a brake pipe flow indicator. During pressure maintaining operation, if markedly increased air flow into brake pipe becomes evident, be alert for the following procedure:

   1. Brake application being made from the rear end.
   2. Bad leakage has developed in the brake pipe or hoses back in the train.

g. In order to secure a reliable release of the whole train, the minimum total brake pipe reduction should be approximately 10 psi.

h. With pressure maintaining, do not attempt to release the brakes in just a portion of the train by means of a short time in release and then returning to application. This will set up false brake pipe gradient conditions. With a sizeable number of ABD type valves in the train a complete release may occur anyway.

i. Graduated release of AB or ABD type freight brake control valves is not possible. If too much brake is obtained on an initial reduction, and speed and track conditions permit, make a release of brake and reapply. Otherwise, allow the train to stop.

7. Pressure Maintaining and Dynamic Brake Operation

a. This is the most common combination of braking on grades.

b. When the train is going over the apex (top) or crest of a grade, it is optional to use either the train air brake or dynamic brake first.

1. With short light trains, it is the general practice to apply the dynamic brake first. If necessary, the train air brake is added as a supplement to control train speed.

2. With heavy trains, it is preferable to apply the train air brake first. The brake pipe reduction should not be started until the throttle has been reduced to idle and train speed starts to increase. Start the air brake application so that all car brakes will be applied as the rear end passes over the summit. This will allow brake shoes and wheels to warm up to provide effective retardation. The dynamic should be then applied as required to assist in controling speed. The total brake pipe reduction should be slightly less than that required to handle the train with air alone, so that dynamic can be varied to regulate train speed with dynamic help.

c. Depending upon particular grade conditions, try to make the air brake application of such degree that the train will keep rolling (will not stall) through curves and lesser grade portions of the area. Vary the dynamic to control speed on other sections of the grade.

d. Plan brake operation so that maximum or heavy dynamic is not used when rounding sharp curves. Be careful when going through turnouts and switches that too much dynamic is not used.

e. If dynamic brake helpers are used in the train, they should not use dynamic until actually close to the crest or on the descending grade. If too much helper dynamic is applied too soon, severe slack action may result.

f. On grades where a large portion of the retarding force is provided by the dynamic brake, prompt action is imperative if all or a part of the dynamic suddenly becomes inoperative. If this situation arises, probably evidenced by a severe slack-run, loss of dynamic brake amperage, etc., safe practice is to get the train stopped quickly. On heavy grades, speed can get out of control in a very short time, use emergency application without hesitating. Service applications usually react too slowly and allow too much speed increase while they are becoming effective.

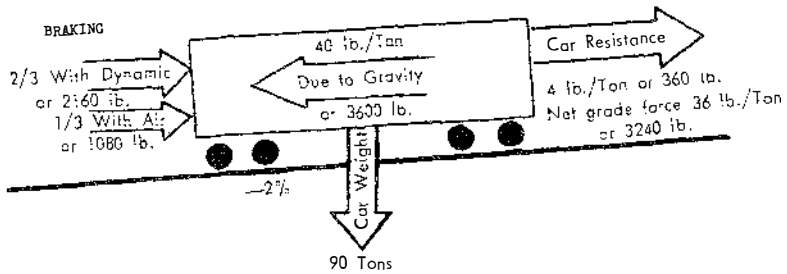


FIG. 117 RELATIONSHIP OF AIR AND DYNAMIC BRAKE

In the example above, Fig. 117 a 90-ton car moving down a 2% grade is under sufficient braking force to balance the pull of gravity downgrade. If 1/3 the braking force is due to the air brake and 2/3 from dynamic brake, and the dynamic brake fails, the car will be subject to an accelerating force due to gravity of 2160 lb. This will cause speed to increase at about .24 mphps. After one minute the car speed will have increased about 14 mph. This situation becomes much more critical with heavier cars on steeper grades.

Even if the addition of 10 psi more brake pipe reduction would eventually balance the grade, at the higher speed, the brake horsepower may be high enough to be excessive for a long grade. Both brake shoes and wheels will probably be overworked.

Again, if dynamic is lost or becomes overworked and ineffective for any reason on a heavy grade:

1. Get the train stopped quickly.
2. Use emergency application.
3. Follow safe practice and local rules before proceeding after such an unplanned stop on the grade.

CHAPTER VII — PASSENGER TRAIN HANDLING

Introduction

Passenger train operation differs from freight train operation essentially because of:

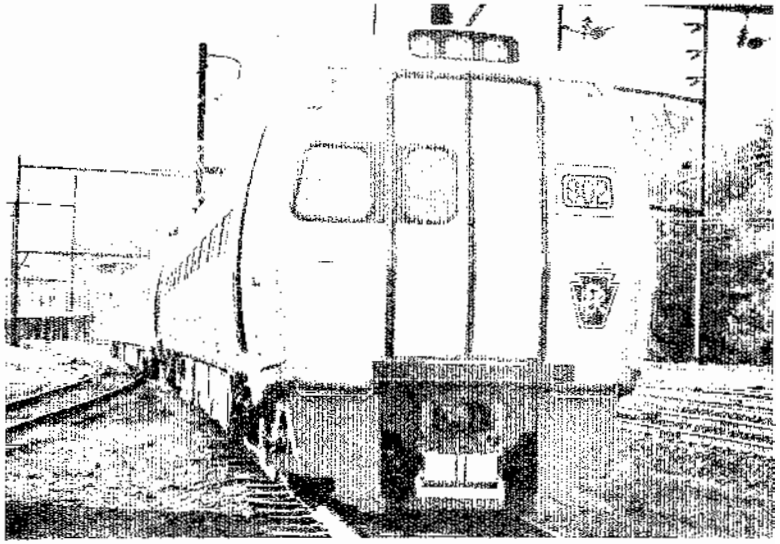
1. Train length—passenger train lengths range from a single car to about 20 cars long averaging 8 to 10 cars. Rarely do passenger trains exceed 25 cars.
   Thus, brake pipe length on passenger trains varies from approximately 85 feet on a single car to about 2,500 feet on a 25 car train, including locomotives. This is equivalent to a short freight train.
2. Weight—passenger trains have loaded weights which usually are not more than 20% heavier than empty weights. Loaded freight trains usually range from two to four times their empty weight.
3. Power and braking level—passenger trains are braked in the high range of empty freight car performance. Similarly much more power is available per ton of weight. Therefore, acceleration and deceleration is much higher than on typical freight trains.
4. Speed—passenger trains usually can operate at much higher speeds than freight trains because of better braking ability and greater available power per ton of weight.

Passenger trains often include self-powered cars where some or all of the axles are driven from a power source. This requires multiple unit control (usually termed M.U.) so that all powered axles in the train consist respond alike. The most common form is in electrified territory where electric power is supplied to the train by means of a catenary wire suspended above the track or a third rail outside the running rails. Third rail operation is the usual form of power distribution on mass transit and subway operations. The suspended catenary or trolley wire is most often employed in railroad electrification where locomotive hauled trains and electric multiple unit car trains will operate over the same tracks.

Other forms of self-powered cars operate with multiple unit control. These power sources can include diesel engine or gas turbine electric drive or hydraulic drive.

The braking systems employed are essentially independent of the particular traction power system employed although the source of compressed air and the number of control stations on a car will vary.

When trains are locomotive powered the air compressor of the locomotive supplies the brake system and auxiliary air uses. When cars are electric multiple unit type smaller motor driven compressors on several or all the cars work together to provide the compressed air needs of the train. M.U. cars usually have motor driven compressor units which include highly efficient after-cooling and moisture separation equipment. Thus, exterior radiating pipe and second main reservoirs are not required.



METROLINER ELECTRIC MULTIPLE UNIT
Mainline Hispeed Passenger Train
P-Wire Power and Brake Control
FIG. 118

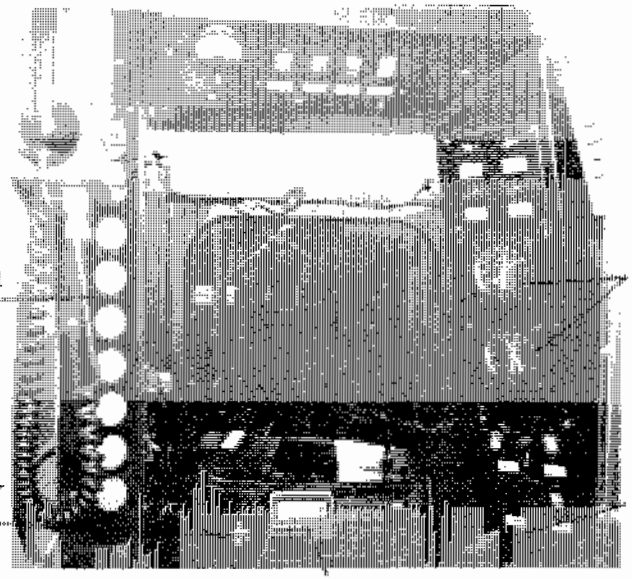
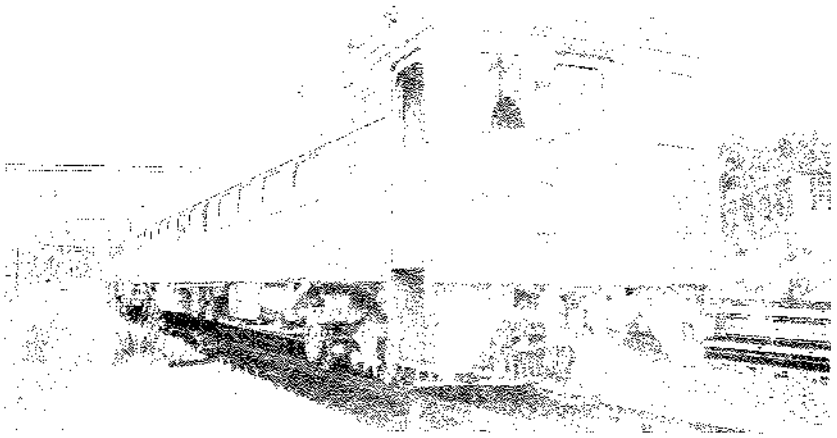
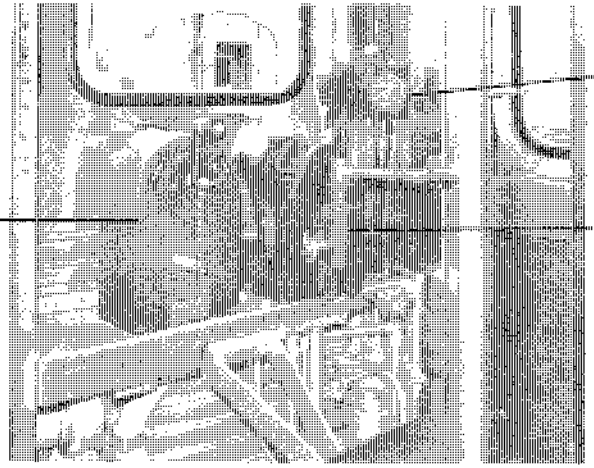


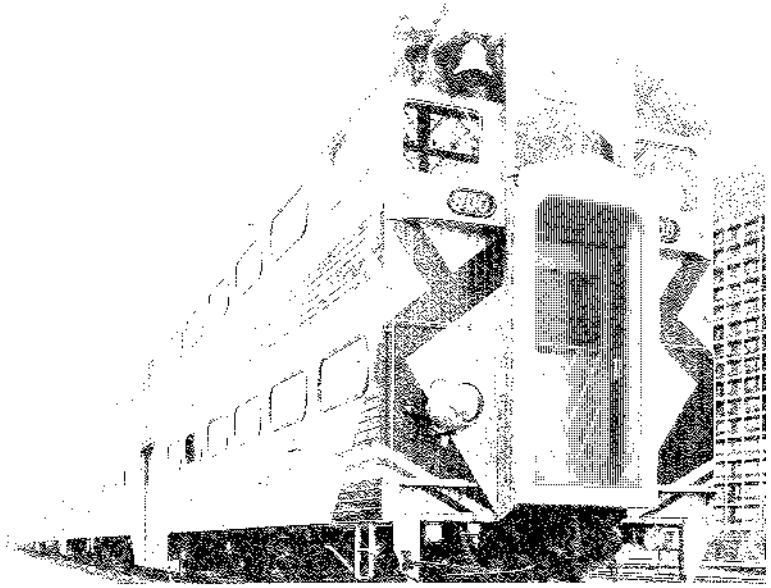
FIG. 119 METROLINER CAB



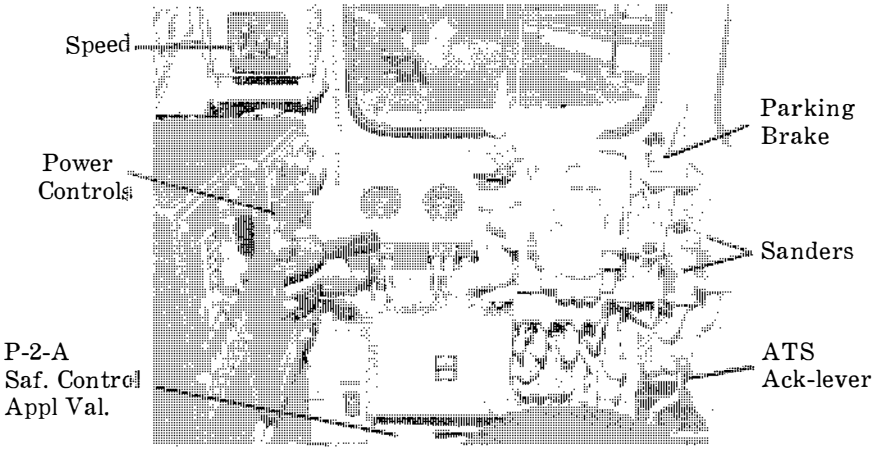
SUBURBAN ELECTRIC MULTIPLE UNIT TRAINS
26-R TYPE EQUIPMENT



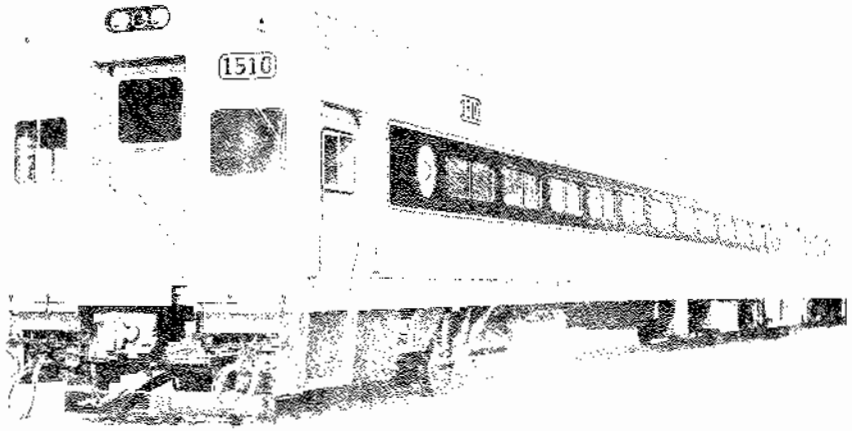
CONTROL CAB ELECTRIC MU CAR
26-R EQUIPMENT
FIG. 120



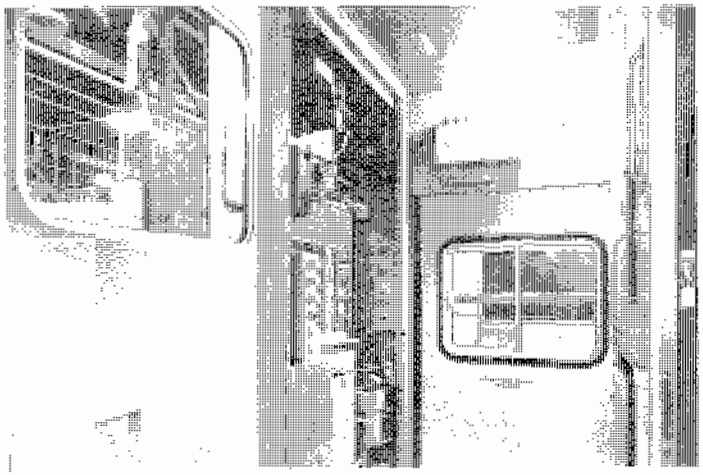
CAB CONTROL CAR
BI-LEVEL SUBURBAN PUSH-PULL TRAINS
LOCOMOTIVE POWERED
26-C EQUIPMENT



CAB OF CAR CONTROL CAR
26-C REAR END CONTROL
FIG. 121



SINGLE DECK CAB CONTROL CAR OF
SUBURBAN PUSH-PULL TRAIN
LOCOMOTIVE POWERED
PS-68 EQUIPMENT



VESTIBULE CAB OF SINGLE DECK
CAB CONTROL CAR
PS-68 EQUIPMENT
FIG. 122

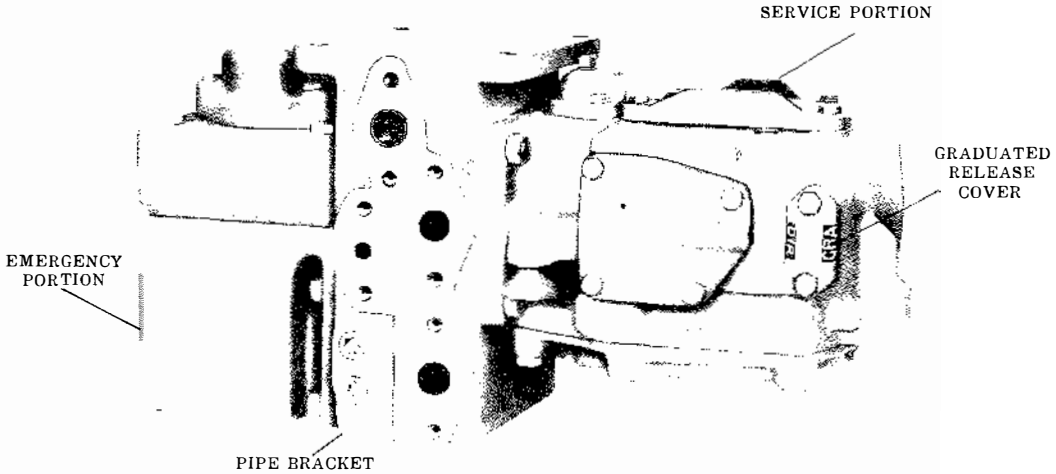
Examples of several modern passenger trains having various types of brake equipment (modern) are illustrated in figures 118, 119, 120, 121, and 122.

Passenger Train Brake Equipment

1) *Automatic Air Brake System*

The passenger and freight train pneumatic brake systems operate basically the same. The main difference is that passenger car and passenger locomotive brake equipment can be positioned for either direct release, as freight equipment operates, or for graduated release. This selection is made on the entire train at the control valve on each car and each locomotive unit by positioning a release cap, see Fig. 123, below.

With the cap positioned for direct release, a small increase in brake pipe pressure will fully release the brake cylinder pressure. With the cap

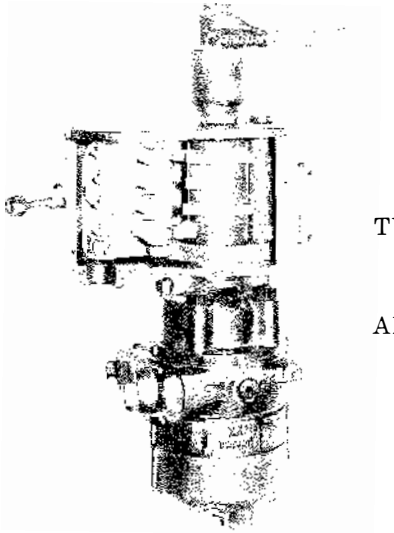


26-C CONTROL VALVE
FIG. 123

positioned for graduated release, a small increase in brake pipe pressure will cause a proportionate decrease in brake cylinder pressure. It permits the engineman to make a heavy brake application at high speed, and then reduce the brake cylinder pressure as the speed decreases. An increase in brake pipe pressure can be made at any time. After a partial release, a re-application of brakes will be more effective at a quicker rate as there is no loss of time or pressure due to brake cylinder piston displacement. This system is on cars with UC Valve Equipment or D-22 Valves, 26-C or 26-R valves and locomotives with 24-RL or 26-L equipments.

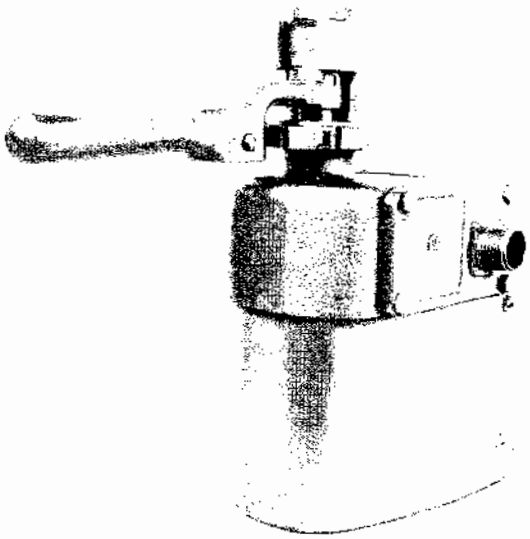
In case there are cars in the passenger train with freight brake equipment, it is not possible to graduate these off. On the first graduation the AB type valves will completely release. If there are too many AB valves in the passenger train, brake manipulation must be changed to handle the train similar to a freight train. In this case the passenger type air brake control valves should have their graduated release caps repositioned for "direct release".

Graduated release operation will work satisfactorily up to train lengths of approximately 26 cars or a total train length including locomotives of approximately 2500 ft. If the train is longer than this, graduated release should not be attempted and the graduated release caps on all cars so equipped should be placed in direct release position.



TYPICAL ELECTRO PNEUMATIC BRAKE VALVE AMUE EQUIPMENT

FIG. 124



PS-68 E.P. BRAKE VALVE

FIG. 125

2) *Electro-Pneumatic Systems*

AMUE Type

The electro-pneumatic brake system includes magnet valves to control brake cylinder pressure in conjunction with operation of the automatic air system and multi-wire electric circuits trainlined through each car. The automatic brake valve has a built-in drum-type electric switch, Figs. 124 & 125. The drum and rotary valve rotate as a unit with the brake valve handle. The position of the drum energizes the corresponding electric circuits. One circuit energizes the release magnet valve located at the control valve on each car to close the brake cylinder exhaust passage to the atmosphere. A second circuit energizes the service magnet valve at the control valve on each car to open a passage between supply air and the brake cylinder. Brake pipe pressure is also reduced. When the brake valve is placed in emergency position, the third circuit energizes an emergency magnet at the control valve on each car to locally vent brake pipe to atmosphere. This causes all control valves to assume emergency position at virtually the same time. The advantages of this system are (a) rapid response of brakes to brake valve manipulation, (b) ability to hold brakes applied while recharging the brake system, and (c) the pneumatic system is automatically in operation at all times in case of electrical failure.

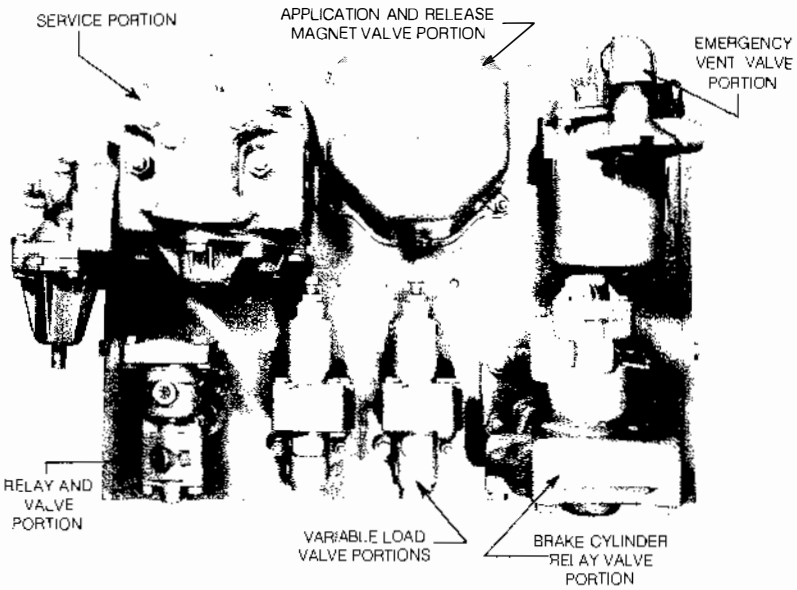
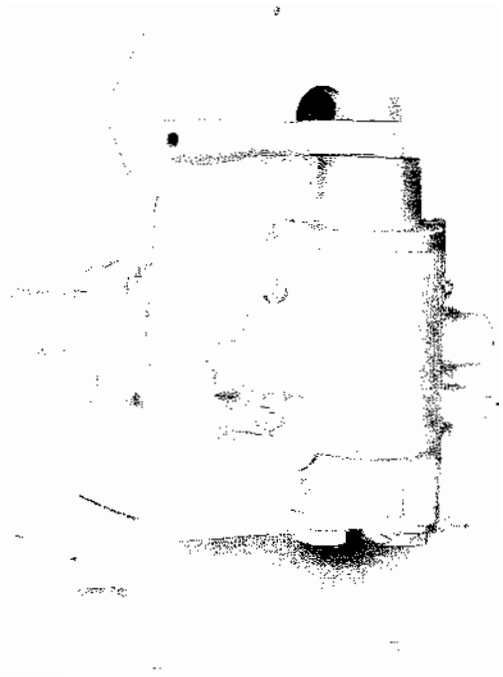


FIG. 126

PS-68 OPERATING UNIT

PS-68 Type System

This electro-pneumatic brake system is similar to the previously mentioned AMUE equipment. There is a drum switch built into the engineman's brake valve. See Fig. 126. Movement of the brake valve handle energizes the train line circuit, causing brake system response on the entire train. Three separate circuits can be energized by the brake valve. The first closes the release circuit losing the brake cylinder exhaust port of the car's control unit in holding position. Next, the service application circuit provides for a local service rate of brake pipe exhaust at each car, setting the brakes, when brake valve handle is placed in this position. Finally, there is the emergency application circuit, which when energized, causes an emergency rate of brake pipe reduction thru the use of the emergency rate exhaust port on all cars of the train. The brake cylinder pressure of each car is developed by the PS-68 control unit, Figure 123, same as in the AMUE system.



26-B-1 BRAKE VALVE
CS-1 OR 26-C EQUIPMENT

FIG. 127

CS-1 Type

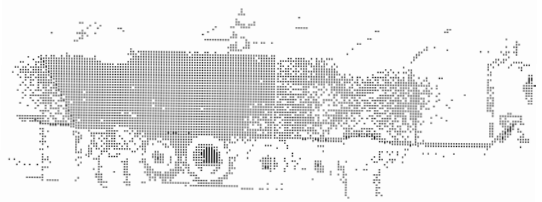
The CS-1 equipment for commuter cars is an electro-automatic air brake equipment utilized one double-acting magnet valve at each control valve on each car or locomotive in the train. While the three-wire concept is retained the operation is basically different from the HSC system, since CS-1 electrically varies brake pipe pressure. A typical automatic brake valve (Fig. 127) pilots a master controller to energize the wires as determined by the differential between equalizing reservoir and brake pipe pressure. When the application wire is energized, the application portion of the magnet valves, Fig. 128, will vent brake pipe pressure locally, thus improving transmission times. The control valve will respond to the brake pipe reduction and furnish a proportionate air pressure to the brake cylinder relay valve. When a release is called for, the release portion of the magnet valve on each car will connect supply or main reservoir air to the brake pipe. This provides a rapid recharge of the air brake system after each brake application. As with previous equipments the pneumatic operation follows the electro-pneumatic, so that a failure in the electrical circuits will not preclude a normal brake response.

Another development of this equipment is the availability of continuous blending valve, Fig. 129 with dynamic brake, if desired. This is accomplished by the addition of a torque motor or compensating magnet in the control pipe between the control valve and the brake cylinder relay valve.

Analog Type or "P" Wire Equipment

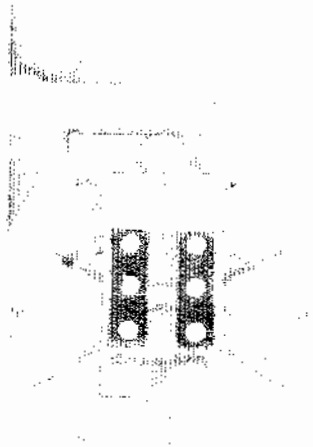
A large number of commuter cars designed since 1965 have been equipped with an electronic control system, commonly referred to as a "P" wire or analog system usually designated RT-5 equipment. The flexibility of this system makes it readily adaptable to either manual or automated train operation. In the basic system the "P" wire is a loop circuit trainline wire from the master controller in the controlling cab, connected through each car to the rear of the train and a return to the controlling cab. A single-handle master controller, similar to Figure 130, Page 181, is used to vary the current in this wire, normally between 0 and 1 ampere maximum. The standard arrangement has been for the lower half (0-500 milliamp) to be used to control braking and from 500-1000 milliamp for power. In the braking mode 0 amps is maximum braking and 500 milliamps is release. The electronic control unit, Fig. 132, on each car provides many features which are desirable in a highly responsive system. This unit responds to the variations in the "P" wire current and electrically determines the desired "call" for brake to correspond to the value of the "P" wire. By converting the amperage signal in the "P" wire to a voltage signal to the control system, the unit thus applies or releases the brake. The pneumatic control unit, Fig. 133, develops brake cylinder pressure which is converted to an electrical feed-back to the electronic control unit on each car to balance the call for brake and cause a lapping of the unit. This is best illustrated as follows:—

"P" Wire	Call for Brake	Brake Cylinder Feedback
500 milliamps	0 volts (release)	0 volts
0 milliamps	Neg. 10 volts (Max. brake)	Pos. 10 volts



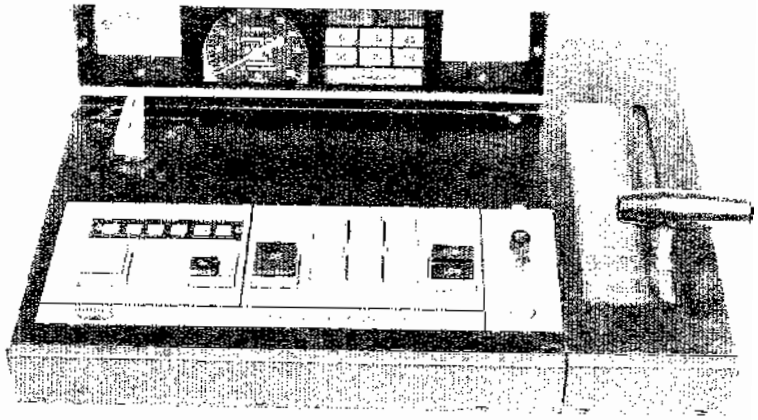
APPLICATION AND RELEASE MAGNET VALVE
RT-5 OR CS-1 EQUIPMENT

FIG. 128



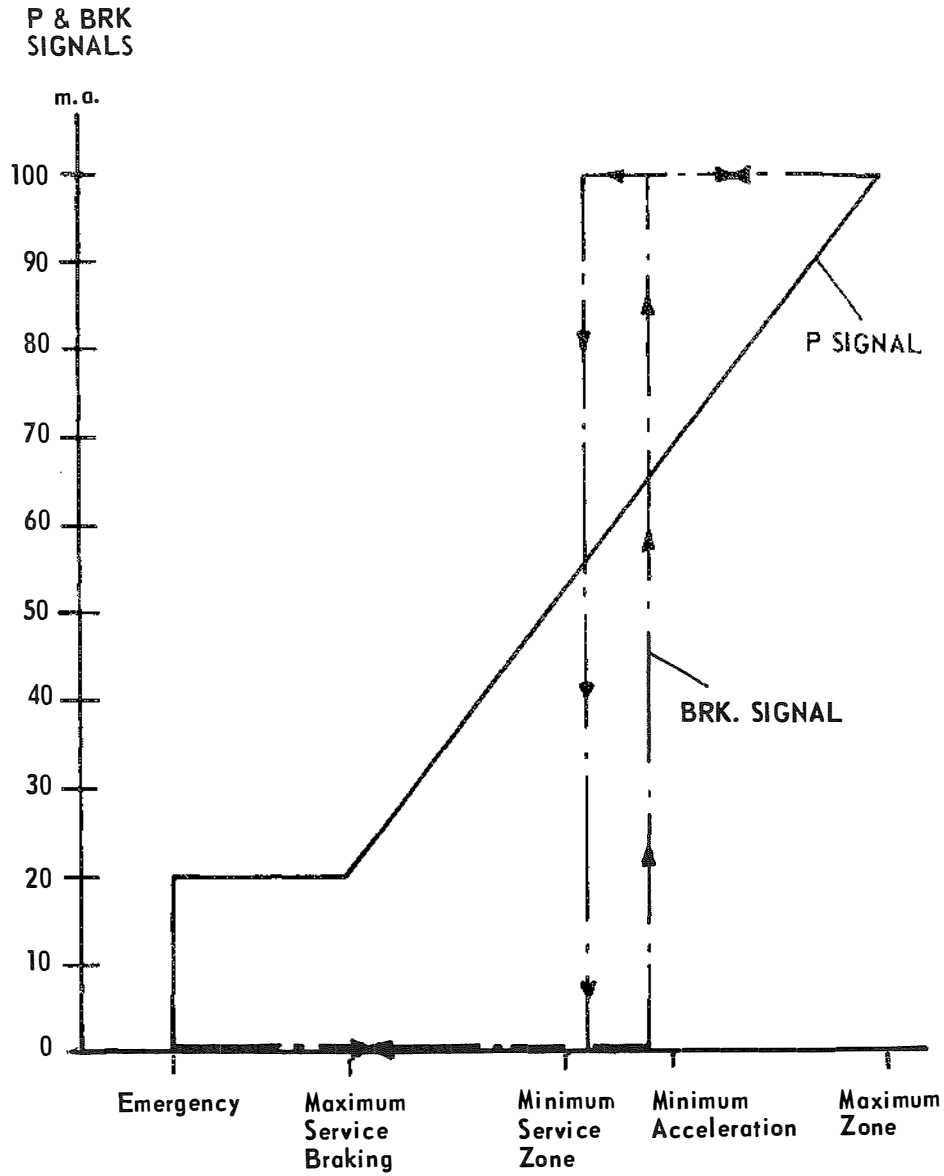
BLENDING VALVE
RT-5 EQUIPMENT

FIG. 129



MASTER CONTROLLER
RT-5 EQUIPMENT

FIG. 130



RT-5 CURRENT ANALOG POWER AND BRAKE CONTROL

FIG. 131

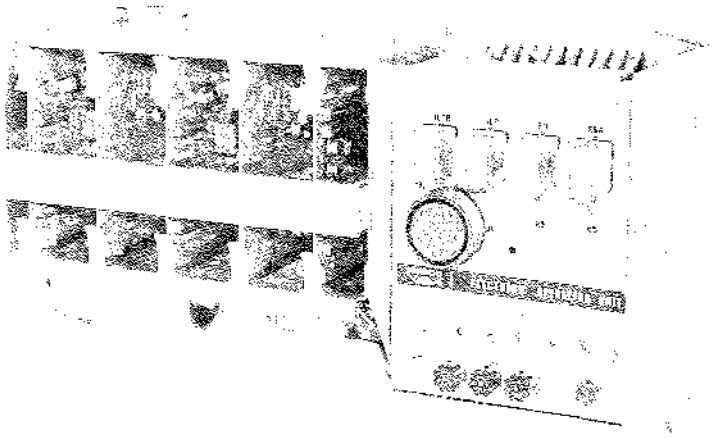
3) *Dynamic Brake*

The dynamic brake can be used in conjunction with either a pneumatic or electro-pneumatic brake system. It may be designed so that when the dynamic brake is effective the air brake is locked out on that unit, or the dynamic brake is continuously blended with the air brake system and as dynamic braking effort changes brake cylinder pressure automatically changes to provide the desired retardation. The latter system has been used on some of the newer multiple unit self-propelled cars.

4) *Wheel Slide Protection*

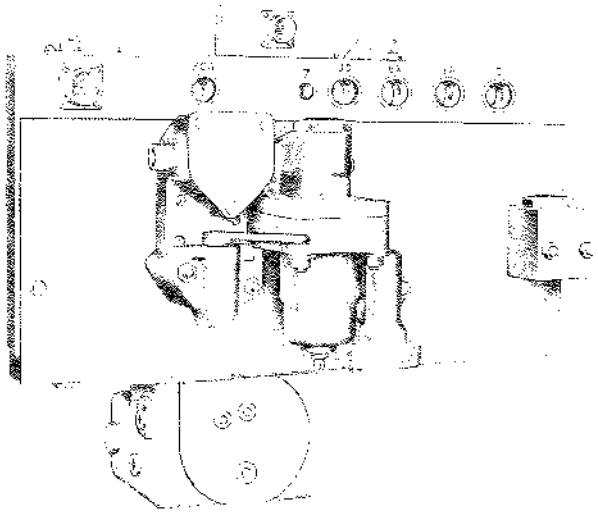
A wheel slide protective system may be integrated with any of the braking systems using truck-mounted brake cylinders or brake units. A mechanical or electrical sensing device will detect either a sudden change of wheel speed or a difference in speed between axles on the same truck and signal for the Decelostat or Rolokron to momentarily release brake cylinder pressure on that truck. At the end of a predetermined time, or when the slide is corrected, the brake cylinder pressure is restored. Each Decelostat or Rolokron device controls one truck only. Fluctuation of brake cylinder pressure is shown on the brake cylinder gauge; however, it must be recognized that the brake cylinder gauge will indicate the pressure only on the truck to which the gauge is piped, not the entire train. Repeated operation of the Decelostat or Rolokron indicates that the available rail adhesion is being exceeded and maximum braking ability is not being utilized. Utilizing maximum braking ability will result in the shortest stop.

Since the converted call for brake is a negative voltage signal, any positive voltage signal introduced into the blending circuit of the electronic operation unit will tend to balance or reduce the call for brake. Currents measuring dynamic braking, load weight, speed, etc., are introduced and this is where the flexibility develops. By providing positive voltage signals from the dynamic brake, load weighing transducer and a speed signal, the call for brake can be varied according to the empty or loaded weight of the car and the operating speed. In this manner the braking on cars is closely controlled according to the existing conditions.



RT-5 EQUIPMENT ELECTRONIC OPERATING UNIT

FIG. 132



R-5 EQUIPMENT PNEUMATIC OPERATING UNIT

FIG. 133

Passenger Train Handling

1) *Standing at Stations*

Modern equipment has very little static resistance so a slight grade could cause a train to move while passengers are loading and unloading. A minimum train brake application can be left on while standing in stations to avoid movement and possible injury to passengers.

2) *Starting Trains*

When starting passenger trains with slack between cars on level track, the throttle must be handled so as to move the locomotive very slowly until the entire train is stretched. The train can then be accelerated rapidly. If the train consists of equipment with little or no slack it can be accelerated rapidly from a standstill to maximum permissible speed. Placing the "road service switch" on each unit of a multiple unit locomotive in "road" position will assure a slow smooth start. The "switching" position on each unit of a multiple unit locomotive provides for a faster start.

When starting passenger trains with slack between cars on a descending grade extreme care must be exercised until the entire train is in motion. In the case of equipment with minimum slack, the train can be accelerated more rapidly.

When starting on an ascending grade care must be taken to open the throttle and be assured that some power is applied before brakes are released. This must be done to prevent the train slack from running backward.

A third condition may exist when operating a train under adverse rail conditions. In this case, regardless of train consist, the throttle must be manipulated so as to prevent excessive wheel slipping due to loss of adhesion. Throttle movements must be such that increases of power are not made at a rate greater than the wheel-to-rail adhesion can withstand.

The engineman is not usually aware of the condition of the equipment until he has started the train, so the departure from the first terminal requires additional concentration and care. The train should be handled at this time as if the slack problem were the most adverse.

3) *Stopping Immediately After Starting*

On occasion, as a train is starting from a station, a condition may require an engineman to stop the train. Unless this is an emergency situation, immediately place the automatic brake valve handle in service position before removing power.

4) *Running Test*

A running test must be made as soon as train speed permits after leaving (a) an initial terminal, (b) a point where motive power or engine crew or train crew have been changed, (c) a point where a brake pipe angle cock or end cock have been turned, except for cutting off cars from the rear of the train, (d) a point where electro-pneumatic circuit power

cables or jumpers have been disconnected, or (e) points designated in special instructions. This consist of a brake application of sufficient force to ascertain whether or not the brakes are operating and the train is decelerating properly. If air brakes do not operate properly, the train must be stopped, the cause of failure ascertained and corrected, and the running test repeated.

5) *Making Stops*

A rough relationship between miles per hour and feet per second is "one and one half times the miles per hour equals feet per second". Accordingly a train moving 70 mph is traveling approximately 105 feet per second. If the braking system on the train required 3 seconds elapsed time to become effective, the train will move 315 feet before brake retardation is effective. After the brake application becomes effective, the type of brake shoe on the majority of cars will determine the manner in which the train should be handled during the balance of the stop.

Brake shoe materials are basically divided into two categories: low friction and high friction. A characteristic of low friction brake shoes is that as the speed reduces, with pressure remaining constant, the coefficient of friction of the shoe increases. The high friction brake shoe coefficient of friction will remain more nearly constant throughout a stop. In either case, high performance passenger train schedules require heavy braking at the beginning of the brake application so that reduction of speed will be rapid. As speed decreases, brake handling should vary, depending on the type of air brake equipment in the train, including types of brake shoes.

With low friction shoes too much deceleration may be encountered below 15 mph unless the train brake cylinder pressure is reduced. With high friction shoes, and their more constant coefficient of friction, a comfortable stop can be made without reducing the train brake cylinder pressure as much, if at all.

Keeping the throttle open while braking to keep the train stretched is believed unnecessary and foolish for braking a train of high class passenger equipment. It is a waste of fuel and an abuse of equipment to attempt to accelerate and decelerate at the same time. If excessive slack exists in the train it may be desirable to use the throttle while braking to keep the train stretched but care must be taken to observe the ammeter and prevent traction motor current from increasing while brakes are applied by reducing the throttle position.

If all cars and locomotive units have brakes set for graduated release, station stops should be made with one brake application and release. The initial reduction should be no less than 8 psi. Allow several seconds for the slack to adjust. Depending upon conditions, this should be followed by one or more further reductions as necessary to develop the desired retardation. Total reduction should be between 12 and 25 psi.

When the speed has decreased or decelerated rate is too high, brake cylinder pressure should be reduced in graduated steps. This is accomplished by moving the brake valve handle from lap to running position and return to lap position, or with the 26 type, move the handle slightly toward release position in the application zone. In either case the equalizing reservoir gauge should show an increase of approximately 4 psi. Do not attempt a further graduation after the brake pipe pressure has been restored to within 10 psi of the standard brake pipe pressure. Graduations should be spaced so a relatively low brake cylinder pressure will be retained when the train is moving 15 mph or less, especially with low friction shoes.

If a train is moving in excess of 30 mph and is set for "direct" release, station stops should be made using two brake applications. Each application may consist of one or more brake pipe reductions. The initial reduction should be no less than 8 psi. Make sufficient additional reductions to obtain the desired retardation. Time should be allowed between reductions to permit the adjustment of slack. The first application should be of sufficient amount that if allowed to remain applied, it would stop the train short of the desired point.

When speed has reduced to approximately 25 mph, brakes should be released. Immediately after the brakes have started to release, move the handle to service position. As soon as air starts to exhaust from the discharge valve, place the handle in lap position. As the stopping point is approached, make a minimum brake pipe reduction so the stop will be completed with a moderate application. If track profile and brake shoe material permit, brakes should be released just before the train comes to rest. This is to minimize truck surge.

The rapid transmission and response of brake equipment to brake valve handle movements on commuter trains equipped with either diaphragm type equipment, such as No. 26 or electro-pneumatic brake equipment, eliminates the necessity of waiting for slack action within the train to adjust itself.

6) *Push-Pull Operation*

Push-pull train operation applies to trains where the locomotive is always at one end of the train and power and brake control can be exercised either in the locomotive cab or in a control station in a car at the opposite end of the train. It is particularly advantageous in suburban services with stub-end terminals.

In order to make this type of train operation possible, the normal multiple-unit power control wires are run through the train. Control of the train brake system requires a typical automatic brake valve in the cab of the control car. A supply of main reservoir pressure is essential for the cab control car automatic brake valve. This is obtained by either running a main reservoir pipe through all cars from the locomotive or equip-

ping the cab control car with an air compressor. Inspections and tests with this type of equipment must be made from the control station to be used.

The tendency is to stretch the train when pulling the train with the locomotive. The cars closest to the locomotive are subjected to the greatest stretching forces and potential adverse slack action.

Handling the train from the cab car end with the locomotive pushing the train results in a different slack situation from that normally experienced with a locomotive controlled train. With the locomotive pushing, train slack is bunched most of the time and the throttle can be advanced rapidly. This is the best situation from a braking standpoint with the train brakes applying serially from the front to rear of the train.

Handling Passenger Trains on Grades

1. *Braking on Grades*

Operating passenger trains down long and heavy grades requires the use of the train brake system to hold the speed steady and within authorized limits as well as to be able to make a stop anywhere on the grade. Speed limits are established so that wheels or discs and brake shoes will not be overworked if limits are observed with normal consists.

Simply stated braking horsepower per wheel or disc is:

$$\frac{\text{Retarding force in lb x speed in feet per second}}{550} = \text{bhp}$$

In English speaking countries speed is usually stated in miles per hour, which is 1.467 x feet per second:

$$\text{bhp} = \frac{F_R\ (\text{lb}) \times V\ (\text{mph})}{375}$$

where bhp = brake horsepower
F_R = retarding force lb
V = speed in mph

The shoes and wheels or discs will become hotter if the retarding force is increased and the brake shoes will wear faster, at least varying with the square of the force. Generally, brake shoes and wheels or discs will give satisfactory service on grades where brakes are continuously applied 20 minutes or more if the average brake horsepower per wheel or disc is kept within the following values: —

Nominal Wheel Diameter	Average Brake Horsepower Per Wheel
30 in.	22 bhp
33 in.	25 bhp
36 in.	30 bhp
38 in.	35 bhp
46 in.	40 bhp

Dynamic brake can be of considerable assistance in grade operation since it can absorb braking horsepower that would otherwise have to be absorbed by the wheels or discs. It can allow higher speeds to be operated without overworking the wheels, discs or shoes. However if dynamic is not available or becomes ineffective when descending a grade, speed must promptly be reduced to a value that will allow the friction brakes to handle the brake horsepower without overworking wheels, discs or brake shoes.

2. *Use of Dynamic and Air Brake*

On light to medium grades, up to about 2%, apply the train air brake first and then the dynamic brake. This is good practice and will prevent a disturbing slack run-in if dynamic is applied first and subsequent run-out as the air brake application takes effect on cars. Reduce the throttle gradually to idle and make a 7 to 12 psi brake pipe reduction holding the locomotive brakes released. As brake pipe exhaust ceases, gradually apply the dynamic brake. The air brake application on cars may be increased if necessary to provide sufficient retarding force. However, if more than about 17 - 18 psi brake pipe reduction is required be alert for conditions which may cause hot wheels or discs and may require reducing speed to a considerably lower range. Dynamic brake on most passenger locomotives so equipped has its maximum effectiveness at about 25 - 28 mph.

On heavy grades, generally 2% or more, start the dynamic brake application sufficiently in advance of the start of the down grade to gradually and gently bunch slack in the train. When the dynamic reaches its maximum retarding force it may be necessary to supplement this force by using the car air brakes. Make light brake pipe reductions until the proper speed is obtained. Allow sufficient time between applications to allow the train slack to readjust. A safe practice is to hold the speed to that which will not require a grade balancing application over about ½ of the normal full service application available hence, the grade balancing application should not be more than a total of 13 - 14 psi brake pipe reduction.

If grade and curvature conditions subsequently allow release of train air brakes, graduate off in steps, allowing sufficient time between graduations for the train slack to readjust. When the train brakes are released and there is no further need for dynamic brake retarding force, release the dynamic gradually, remembering that the slack is bunched.

3. *Descending Grades With Air Brakes Only*

In case the dynamic is inoperative or if locomotives are not equipped, operation on downgrades must be handled with the air brakes on the train. Start the brake application sufficiently in advance of the crest of the grade to allow slack to adjust gradually.

Care must be employed in the use of locomotive brakes so as not to overwork wheels and shoes. Try not to exceed the locomotive brake cylinder pressures at the various speeds indicated below. Do not fully release them too quickly or slack may run out harshly.

Speed MPH	*Max. locomotive brake cyl. pressure so as not to exceed 30 bhp/wheel	35 bhp/wheel	40 bhp/wheel
10	27 psi	32 psi	37 psi
15	19 psi	22 psi	25 psi
20	14 psi	16 psi	19 psi
25	12 psi	14 psi	15 psi
30	10 psi	11 psi	13 psi

*This is based on a typical diesel electric or electric locomotive with approximately 30,000 lb weight per wheel and braking ratio of 55% at 50 psi with cast iron shoes or 27.5% at 50 psi with high friction composition brake shoes.

Since passenger cars usually have only about ½ of the weight per wheel as locomotive, brake cylinder pressures can be about double that on locomotives for the same brake horsepower per wheel. In long grade operations most car wheels or discs can absorb 30 brake horsepower satisfactorily. Thus average car brake cylinder pressures and corresponding brake pipe reductions should not normally exceed:

Speed MPH	Average Car Brake Cylinder Pressure	Train Brake Pipe Reduction
10 mph	54 psi	21 psi
15 mph	38 psi	16 psi
20 mph	28 psi	13 psi
25 mph	24 psi	10 psi
30 mph	20 psi	8 psi

Car air brakes should be graduated on or off as required to control train speed. Wait sufficient time between graduations to allow slack to readjust, if speed conditions will permit.

CHAPTER VIII — TRAIN MOVEMENT AND RAILROAD CAPACITY

Railroad capacity is a subject which concerns all of us connected with railroading in a rather direct way. Railroad capacity is a measure of the ability of our industry to provide the public with a transportation service so vital to our highly developed modern civilization. Steel wheels rolling on steel rails provide the lowest resistance and horsepower required for movement of a given mass in the speed ranges from 30 to 150 mph. Thus railroads potentially provide the most economical form of ground transport. The essential feature of railroads is low cost mass transportation.

Railroad performance—or how we measure how well we do what the public demands of us—can be described in various ways. Some terms have more meaning than others depending upon the view point from our individual or departmental position. Some of these descriptions are:

"Billion ton miles per year" used by government, AAR and public to describe how much service we provide in comparison to our competition — trucks, airlines and waterways.

"Ton miles per freight train hour" is often used by operating and mechanical departments to tell how well we move the freight given to us. It involves how trains are made up and what power is used.

"Train movements per hour, day or week" is used by operating and signal departments to tell how well the over the road operations are going within the capabilities of the signal and traffic control system.

"Passenger miles per day, week or month" tells traffic, operating and mechanical departments the demand for service, from which the number of cars and trains required can be determined.

"Gross tons per mile of track (hour, day, week) tells how much a section of railroad is being used. This is measured against maximum capacity to see the degree of utilization demanded. It gives indications of how much maintenance is required.

Notice that each description includes a time factor. Since railroads exist to provide transportation by the movement of large blocks of tonnage or groups of people in trains, our major interest is in those areas relating to factors which control the number of trains which can be operated in a given time period.

It is essential to know the capacity so that the size of the railroad plant needed to perform the service required can be determined. Since public demand for shipment of traffic involves many movements of seasonal nature, the peak capacity of most railroads must be several times the nominal average throughout a year.

Trains must be operated safely. This means they must be spaced far enough apart so that a following train can slow down or stop short of

the train ahead and avoid a collision. Basically, the typical signal system divides the track into distances called "blocks". The entrance to each block is controlled by a signal.

More highly developed and sophisticated systems provide continuous indication in the cab of wayside signal ahead. Some systems provide automatic enforcement of any restrictive indication speeds in case the engineman does not respond within a given time.

Laws and rules governing train operation on track equipped with signals require that the train must be able to be slowed or stopped to the speed called for by the indication of the next signal ahead before passing that signal. This must be accomplished with an air brake application *other than emergency.* In effect this means that train stopping ability is primarily related to the full service train brake application! Theoretically, maximum speed is the highest speed from which a full service stop can be made before passing the next stop signal. Practically, however, there is extra distance or a "margin of safety" included.

Therefore, the basic operating capacity of a piece of track to handle train movements is dependent upon speed and distance between trains. The three factors involved are:

— speed
— length of signal blocks
— number of blocks trains are spaced apart

This can simply be expressed for single direction operation.

$$C_1 = \text{Operating Capacity} = \frac{\text{Speed x Time}}{\text{Block Distance x Number of Blocks Apart}}$$

Since distances are expressed in feet and speed in feet per second it is convenient to express time in seconds.

$$C_1 = \frac{\text{V (mph x 1.467 x H (hours) x 36000}}{\text{D}_b\text{ (block dist. ft) x N (no. blocks apart)}}$$

For example: With 60 mph operating speed, 6000-ft block distance, trains effectively three blocks apart, what is capacity in trains per hour?

$$C_1 \text{ Copr} = \frac{60 \times 1.467 \times 1 \times 3600}{6000 \times 3}$$

C_1 Copr = 11.7 trains/hour for single direction operation.

This represents the maximum capability of this piece of track to provide for train movements at 60 mph — 11.7 movements per hour. Obviously, larger number of movements can be handled if trains are

spaced closer together. If for example, all trains ride the "yellow" signals "N" will become about 1¼. However, speeds will be lower since all trains must observe the speed of the yellow or 45 indication. Practically speaking, this is about half the maximum speed. Twice as many trains at half speed does not increase the amount of tonnage handled.

When operation in both directions on a single track is required, another, longer distance factor is involved. This is the distance between passing tracks. If operation is one train east and then one train west, trains must wait until the opposing train has cleared.

For example:

Two Direction Operation on Single Track

V = 60 mph operation
D_b = 9000-ft blocks
B = trains effectively 3 blocks apart
S = passing tracks averaging 13.6 miles apart
N = 1, one train east then 1 train west etc.

What is Capacity in Trains per Hour?

$$C_2 = \frac{\text{V (mph) x 1.467 x H (hours) x 3600}}{\text{2 (S x 5280) x Nx Bx D}_b\text{)}}$$

$$= \frac{60 \times 1.467 \times 1 \times 3600}{2\ (13.6 \times 5280) \times (1 \times 3 \times 9000)}$$

= 2.4 trains per hour

As we can see, the capacity of a single track railroad having passing tracks about 14 miles apart in both directions is only about 1/5 of that track for single direction operation. Obviously, it is possible to operate more trains if passing tracks are closer together and traffic allows trains to be dispatched at proper intervals. The reason for this is that one train must clear this section of track before the next opposing train can enter the main.

General practice following traffic flow patterns, which are usually heavier in one direction than the other, is to operate trains in the heavy traffic direction fairly close together in "fleets" or groups. It can be easily appreciated that if one intermediate train of the group does not perform as planned, everything behind it as well as those in the opposite direction are affected severely. It can take many hours to get trains back into schedule.

As far as the public is concerned, it is the productive capacity that counts: regular, safe damage-free delivery, on time, at a reasonable cost. Therefore, we railroaders also have to be concerned with the tonnage of lading we handle in the cars of the trains. Productive capacity is the ability we have to move tons or people measured on a time basis such as tons per hour or day. Public demand and competition from other forms of transport have forced railroads to provide for shipment of much larger quantities of lading per car, in bigger sized cars at faster speeds.

The stopping capability in service braking controls the maximum speeds which can be operated within the signal spacing. Therefore, the ultimate capacity of railroads to do business rests upon proper train brake operation. This is one of the major factors in management of train operation for which the engineman is responsible.

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1. FUNDAMENTALS OF BRAKING
2. BRAKING ADHESION & WHEEL SLIP
3. TRACTION ADHESION & WHEEL SLIP
4. IDAC WHEEL SLIP CONTROL SYSTEM
5. SANDING — WHEEL SLIP CORRECTION
6. DYNAMIC BRAKING SYSTEM
7. RECOMMENDATIONS ON RADIO CONTROLLED LOCOMOTIVE UNIT OPERATIONS
8. REPLACEMENT OF FAILED COUPLER KNUCKLES
9. TRAIN RESISTANCE DATA
10. LOCOMOTIVE PERFORMANCE DATA

CHAPTER VIII

TECHNICAL APPENDIX

Section 1. FUNDAMENTALS OF BRAKING

BRAKE SYSTEM IS REQUIRED TO:

Stop the train
Control the speed
Hold the train stopped

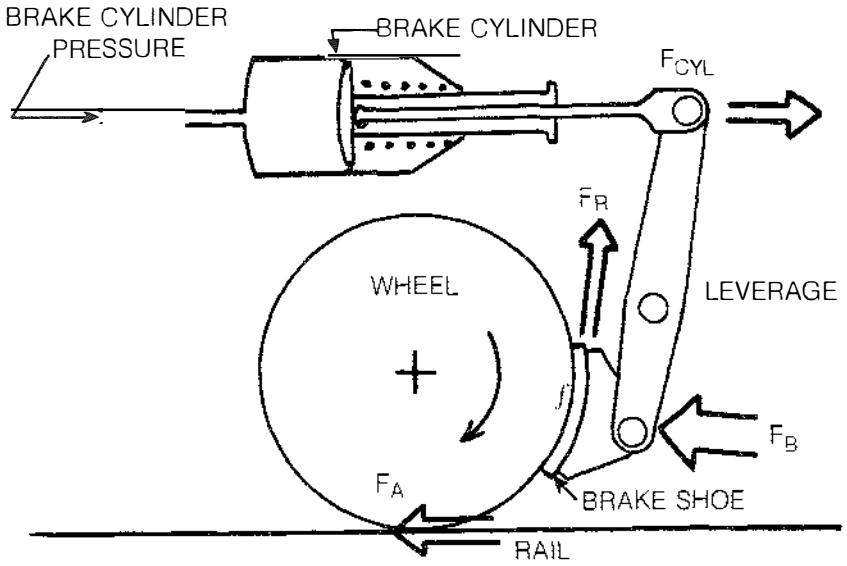
HOW IS THIS ACCOMPLISHED?

By developing retarding force
Commonly by pressing
a brake shoe against a wheel

HOW MUCH RETARDING FORCE CAN BE USED?

Retarding force is limited by
wheel to rail adhesion.
If retarding force exceeds
wheel/rail adhesive force
wheel slide will occur.

The following information gives basic formulas for calculating braking performance.



$$F_R = F_B \times f$$

(Retarding Force) (Braking Force) (Brake Shoe Friction)

$$F_R = (F_{CYL} \times L.R. \times E) \times f$$

(Cylinder Force) (Lever Ratio) (Rigging Efficiency)

Rigging Efficiency includes all losses in the Brake Cylinder and Leverage System

$$F_R \text{ (RETARDING FORCE)} \leq F_A \text{ (ADHESIVE F.)}$$

This means Retarding Force must be equal to or less than the Adhesive Force or wheel sliding will result

Developing Retarding Force

FIG. 134

Braking Ratio

Traditionally the comparative braking ability of a car or locomotive has been described by a term called "braking ratio". Braking ratio is the ratio of the force pressing the shoes against the wheels to the weight of the car or locomotive.

$$BR = \frac{\text{Braking Force (lb.)}}{\text{Weight of Car of Locomotive (lb.)}}$$

Braking ratio is usually stated as a per cent of the weight and is generally computed by:

$$BR_G\% = \frac{P \times L \times A \times N \times 100}{\text{Weight Lbs.}}$$

P = Brake Cylinder Pressure psi
L = Leverage Ratio
A = Area of Cylinder Piston, sq. in.
N = Number of Cylinders Per Car of Locomotive

Braking ratio (BR_G) calculated as above would be the gross braking ratio and does not account for the efficiency of the brake cylinder and leverage system. Since the advent of the high friction brake shoes and widely different rigging designs gross braking ratio is no longer a good yardstick for comparing brake performance. The type of rigging and brake shoes must be taken into account.

Net braking ratio takes into account the rigging efficiency and the above formula would become

$$BR_N\% = \frac{P \times L \times A \times N \times E \times 100}{\text{Weight Lbs.}}$$

Where "E" is overall rigging and cylinder efficiency, usually stated as 50 psi control pressure, and actual shoe force is measured with a calibrated brake shoe.

Generally for equivalent stopping performance the high friction brake shoes use approximately 40% to 50% of the braking ratio employed with low friction (cast iron) brake shoes. However, since the static friction of high friction and low friction shoes is approximately the same, similar static holding ability requires similar braking ratio. Therefore, locomotives with high friction generally have a higher independent braking ratio than with the automatic available for static holding purposes.

Stopping the Train

How quickly will retarding force reduce the speed? The retardation rate due to the retarding force may be calculated as follows:

$$R = \frac{22 \times F_R}{\text{Wt. (lbs)}}$$

(Retarding rate in miles per hour per second)

NOTE: 22 is a constant which allows the use of retardation in mphps and forces and weights in pounds. More accurately 22 is 21.93.

NOTE: F_R is retarding force in pounds

Stop distance is related to speed and the retardation rate as follows:

$$SD = \frac{.733\ V^2}{R}$$

SD is stop distance in feet

V is speed = mph

R is Retardation rate miles per hour per second.

Retarding force required for basic railroad operations is conveniently expressed in pounds per ton.

a. From $F = ma = \frac{w}{g} \times a = \frac{w}{g} \times 1.467A$

Where A = 1 mphps or 1.467 fpsps; W = weight =2,000 lb (ton);
g = 32.17 fpsps (gravitational constant)

$$F = \frac{2{,}000 \times 1.467\ (1)}{32.17}$$

Thus to provide 1 mphps retardation requires

F = 91.16 lbs. per ton

b. Retarding force due to a grade equals % grade times the weight. Thus on a grade of 1% the force required to balance gravity is 1% x 2,000 lb. or 20 lbs. per ton. (See further explanation on Page 162 and examples on Pages 168 and 169)

The acceleration due to a downgrade, or deceleration due to an upgrade, is

$$A_G = \frac{G(\%\ \text{grade}) \times 2{,}000}{91.16}$$

(mphps)

or more simply A_G = G (in decimals) x 22
(mphps)

For example on various downgrades the acceleration due to gravity would be:

A_G = .01 x 22 or .22 mphps on a 1% grade
A_G = .02 x 22 or .44 mphps on a 2% grade
A_G = .03 x 22 or .66 mphps on a 3% grade

c. It is important to know what adhesion is required for any retardation level. The required adhesion is usually termed "adhesion demand" and can be simply found on level grade by:

$$ADH = \frac{\text{Retardation (mphps)}}{22}$$

(Adhesion Demand)

In grade operations the effect of gravity must be considered.

(1) When on any grade, ascending or descending the effective weight on the wheels is reduced in proportion to the grade.

(2) The total adhesion demand when braking on a downgrade includes the equivalent retardation needed to simply balance the force of gravity. Slowing down at 1 mphps on a 3% descending grade thus has a total adhesion demand of:

$$\text{ADH Total} = \frac{(R + A_G)}{22}$$

$$\text{ADH Total} = \frac{(R + 22G)}{22}$$

$$= \frac{(1 + 22\ (.03)\ )}{22}$$

$$= .075 \text{ or } 7.5\%$$

For practical adhesion values attainable on various kinds of track and discussion of wheel slipping refer to Appendix Section II for braking and Section III for traction adhesion.

Braking Horsepower

In addition to the adhesion limitations there are the physical limitations of the wheels and brake shoes to absorb energy. This physical limitation is generally expressed in terms of brake horsepower per wheel.

$$\text{bhp per wheel} = \frac{\text{Retarding Force in (lb)} \times \text{V (mph)}}{375}$$

$$\text{bhp} = \frac{F_R \times V}{375}$$

Experience indicates that the following brake horsepowers per wheel can be absorbed continuously such as on a long grade giving reasonable shoe and wheel service.

33″ — 25 HP
36″ — 30 HP
38″ — 35 HP
40″ — 40 HP

Higher bhp can be used for shorter durations. However 60 to 70 bhp/wheel (or disc) appears to be the upper practical limit. During stops particularly from high speeds considerably higher instantaneous horsepower will be developed for short durations.

SECTION 2. BRAKING

Wheel-To-Rail Adhesion and Wheel Slip

Fundamental to railroad operation is the frictional force existing between the wheels and the rails which is used to impart power and braking forces to the train. The term adhesion as used in railroading means the coefficient of friction between the wheel and rail. Adhesion is determined by applying tractive or brake retarding force to the wheel and finding the force at which slipping occurs for various wheel, rail, track and equipment conditions.

Dividing this friction force by the weight on the wheel gives the coefficient of adhesion:—

$$\frac{\text{Tractive or retarding force (lb)}}{\text{Weight on wheel (lb)}} = \text{Coefficient of adhesion}$$

$$\text{i.e. } \frac{F_t \text{ (or } F_r)}{W} = C_{adh}$$

Example: 3000 lb retarding force on a wheel with 20,000 lb on it is just sufficient to cause slipping.

$$C_{adh} = \frac{3{,}000 \text{ lb}}{20{,}000 \text{ lb}} = 0.15 \text{ or } 15\%$$

As shown on figure 135 the typical adhesion values with steel wheels and steel rails range from about 7% to 25% depending upon speed, type of track and wheel conditions.

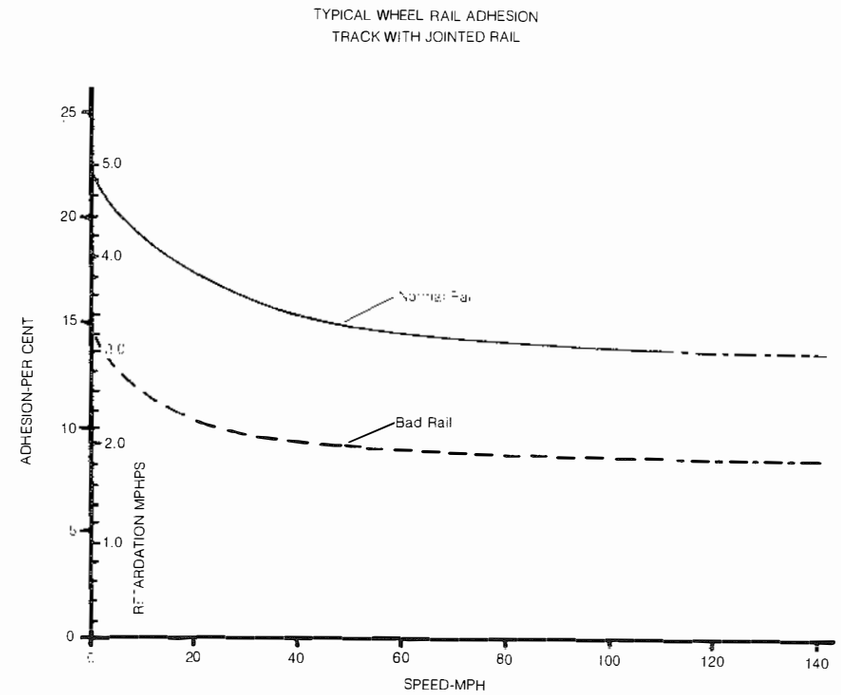


FIG. 135 TYPICAL WHEEL RAIL ADHESION TRACK WITH JOINTED RAIL

On an instantaneous basis a rolling wheel has essentially stationary contact with the rail. The contact area between a rigid steel wheel and the rail is small, ranging from about 1/3 to 3/4 of a square inch depending upon wheel size, contour of wheel tread and rail head and the weight of the wheel. When a wheel slips or slides the adhesion is less than when it is rolling. Sliding adhesion may only be 1/4 or 1/3 of rolling adhesion. Slipping or sliding can cause severe wheel and rail damage. Aside from causing an uncomfortable noisy rough ride, flat spots can lead to subsequent damage to bearings, truck, motors and lading.

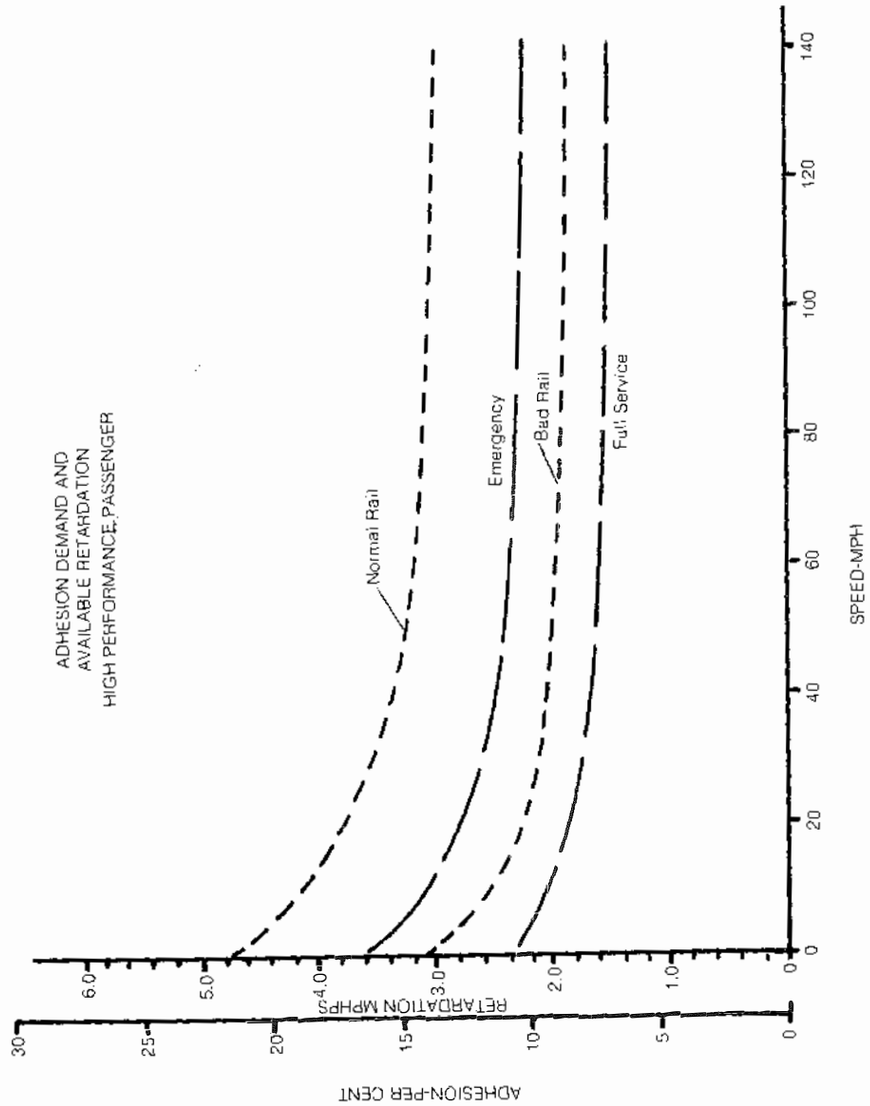


FIG. 136 ADHESION DEMAND AND AVAILABLE RETARDATION HIGH PERFORMANCE PASSENGER

As illustrated in figure 135 adhesion for power or braking use varies with speed, gradually reducing as speed increases. The condition of the rail surface has a major effect on the adhesion available. Oil, grease, moisture, frost, rust, dirt, leaves, mud, etc. reduce adhesion. The type of track structure and curves also affect adhesion, the best being straight level track with continuous welded rail on heavy ties and clean dry rock ballast. The lower of the two adhesion curves captioned "Bad Rail" is typical of track with rail joints and rail surface in poor condition. The upper adhesion curve captioned "Normal Rail" is for ordinary track with rail joints and rail surface in reasonably good rail condition.

Locomotives and cars have braking systems designed to produce braking levels within the limits of adhesion experienced in day-to-day railroad operations. Passenger cars and locomotives usually have maximum braking capabilities between the two adhesion curves shown but closer to the lower curve. The ability to reduce speed, termed retardation, is directly related to adhesion since adhesion tells us just how much retarding force can be used without producing wheel slip. Simply stated,

$$\text{Retardation (mph per second)} = 22 \times \text{adhesion}$$

or

$$\frac{\text{Retardation (mph per second)}}{22} = \text{adhesion}$$

Figure 136 shows typical retardation and adhesion demand for a modern passenger car. Full service adhesion demand is about the same as the lower or bad rail adhesion curve. Adhesion demand in emergency is somewhat above the values represented by the lower curve to take advantage of adhesion available most of the time.

When considering a freight car, the situation is somewhat different since the fully loaded car is often 4 or 5 times as heavy as the empty car. Most freight cars have a single-capacity brake system which has the same braking force whether empty or loaded. The empty condition determines the maximum braking level. Figure 137 shows adhesion demand for a typical 100-ton capacity freight car. Note that there is little likelihood of sliding wheels when the car is loaded. With the empty car there is some liability of sliding wheels with the empty car with cast iron brake shoes on poor adhesion rail, particularly at low speeds.

Adhesion under bad rail conditions can be improved by sanding the rail. Sanding is still the most practical and economical method for improving adhesion as proven in recent extensive investigations. Most poor adhesion rail can be improved almost to the "Normal Rail" adhesion curve by a small quantity of silica sand properly applied just ahead of the wheel rail contact. The sand is crushed to an abrasive powder as the wheels roll over it. The small grains of powdered sand break through the film of contaminant and thus improve adhesion.

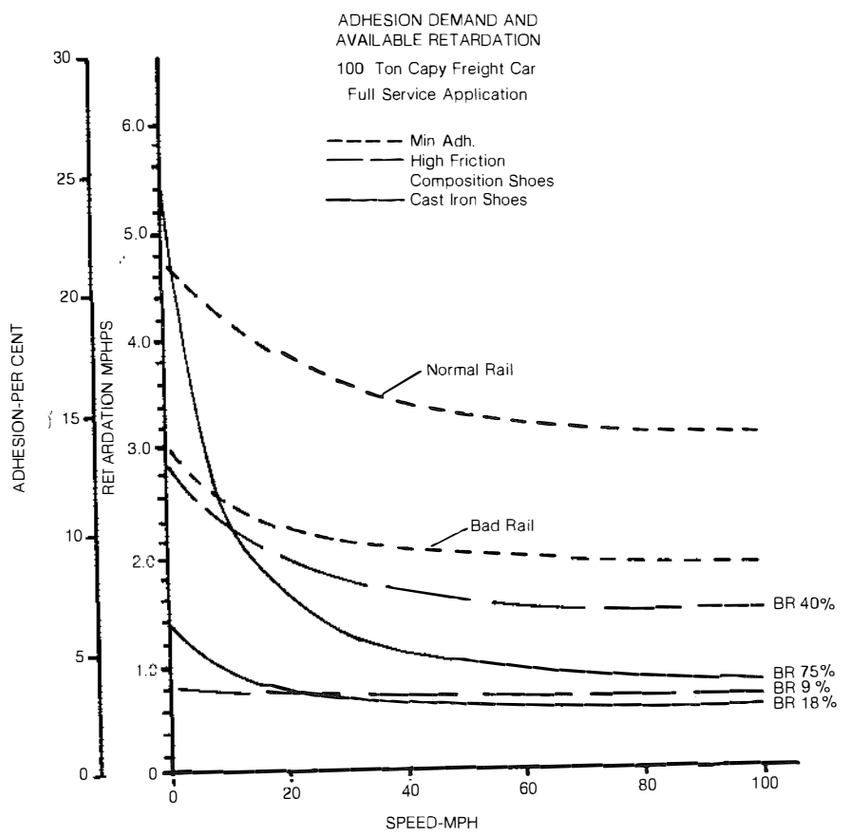


FIG. 137 ADHESION DEMAND AND AVAILABLE RETARDATION 100 TON CAPACITY FREIGHT CAR FULL SERVICE APPLICATION

On passenger cars having fairly high braking levels and adhesion demand, wheel slip detection and control systems are often applied. These systems detect when a wheel is slowing down too rapidly and is likely to slide. The brakes on that axle or truck are momentarily released to allow the wheels to regain train speed and then the brakes are reapplied. Wheel slip-slide control systems can automatically apply sand if the cars are so equipped.

Locomotives and modern multiple unit passenger cars are usually equipped with a traction (or power) wheel slip detection and correction system. These systems detect if an axle is going faster than train speed and cut back power to allow wheels to slow down to train speed. Then power is automatically reapplied at a controlled rate to the extent called for by the throttle position. Traction wheel slip can be damaging to wheels, motors, and track.

SECTION 3. LOAD SENSITIVE BRAKE EQUIPMENT

Chapter III briefly covers brake equipment which varies the braking force in relation to the weight of the car. Primary use of load sensitive brake equipment is on cars having very light empty weight in relation to their loaded weight. Many mass transit cars have used various forms of load sensitive brake equipment for years. However, locomotives and main line passenger or suburban passenger cars have not used this type of equipment because there is relatively little difference between empty and loaded weights, usually not more than 20%.

In general railroad freight train consists empty, partially loaded and fully loaded cars are intermixed. In order to avoid wheel slipping and sliding on empty cars the empty braking ratio and hence the braking ability is limited to practical wheel-rail adhesion values such as illustrated on Fig. 137. Since most cars have single capacity brake equipment, the braking force is the same whether empty or loaded. With loaded weights ranging from two to five times the empty weight, the braking ability of loaded cars varies from about 1/2 to 1/5 of empty cars.

While the obvious reason for load sensitive brake equipment is to avoid wheel sliding when empty or lightly loaded, a second important reason is to provide more uniform braking ability throughout a train. This will lead to smoother braking and can allow considerably higher loaded braking ratios without exceeding the practical empty braking ratios.

In the mass transit field very close scheduling and high density of train movements require a high performance brake system to attain the needed carrying capacity with safety. Uniformity of performance regardless of car loading is beneficial in any system but is paramount if any form of automatic control is employed. Mass transit cars often have rush hour car loadings 50 to 60% higher than empty weight.

Types of load sensitive brake equipment can be generally divided into three main categories:

a. *Load Limiting Equipment*

In load limiting brake equipment the brake cylinder pressure or braking force is limited to a value considerably less than the normal maximum attainable when the car is empty or lightly loaded. At moderate or heavy loaded condition full braking pressure or braking force is allowed to develop. See Figures 138, 139.

1. In the freight brake field, the L-1 Detector Valve is an example of empty brake cylinder pressure limiting equipment. The L-1 Detector Valve limits service brake cylinder pressure to appx. 35 psi regardless of the brake pipe pressure being used. Excess pressure is allowed to spill over into a volume reservoir. This means that the maximum service brake cylinder pressure will be attained with a brake pipe reduction of 13 psi on L-1 Detector equipped cars. Obviously these cars will not be braked proportionately with the other cars when brake pipe reductions are heavier than 13 psi.

   Emergency brake cylinder pressure will likewise be less than normal on the empty car but will be higher than in service. At 70 psi brake pipe pressure emergency brake cylinder pressure will be appx. 43 psi. As brake pipe pressure is increased the emergency brake cylinder pressure will increase. This is because the spillover volume is sized to insure 35 psi will be attained from a full service application at 110 psi brake pipe pressure. The L-1 Detector Valve mounted on the car body measures truck spring deflection when the brakes are applied. It changes from empty to loaded condition when the car is about 20% loaded. In load position the spillover volume is cut out and normal service or emergency brake cylinder pressure develops.

2. *Empty-Load Equipment*

   In order to assure full range proportional control of any degree of service or emergency applications for both empty and loaded car conditions, the empty-load brake equipment is used. As the name implies this is a two step equipment having distinctly different braking force levels for either empty or loaded car conditions. Empty braking forces are usually 35% to 60% of that provided for loaded car condition.

   This type of brake equipment has been employed for cars handling specific ladings which are either empty or heavily loaded when moved over the railroad. Empty-load equipment allows loaded trains to be braked high enough to insure adequate stopping margin beyond the amount of brake needed to balance the force of gravity down grade while not exceeding practical braking levels and adhesion with empty cars.

   Most empty-load equipment includes automatic determination of car load condition by measuring the truck spring deflection. Some special or captive services use a manual changeover from empty to load

which requires proper positioning of a lever or handle to suit car loading condition. Automatic changeover must be used for empty-load equipment used in interchange service.

a. Older empty-load equipments use a changeover valve which is positioned in empty or load in response to a strut cylinder measurement of truck spring deflection. The strut cylinder is mounted on the sprung portion of the car (car body or truck bolster) and measures the distance to the unsprung truck side frame. Change from empty to load or vice versa occurs at about half the normal spring deflection between empty and loaded car condition. This is quite satisfactory for cars which operate either fully loaded or empty. Older empty load equipments use either two brake cylinders (an empty and a load cylinder) or a special differential area cylinder which has two distinct piston areas within one cylinder. Empty condition uses the smallest and load condition the largest effective diameter.

b. Newer empty-load equipments use the conventional single area piston which is large enough to suit the loaded car condition. For empty condition a specific proportion of the loaded car brake cylinder pressure is used. The proportion may be 35%, 40%, 60% etc., depending on the car weight characteristics. New equipments such as the SC-1 utilize a sensor which automatically measures the truck spring deflection during each brake application and do not require the larger complex changeover valves common to the older equipments. A simple proportioning valve and small equalizing volume operate to hold the empty brake cylinder pressure to the proper value for all degrees of brake application or brake pipe pressure. Changeover from empty to load condition occurs at about 20% load similar to the L-1 Detector equipment.

3. *Load Compensating or Variable Load Equipment*

   The third general category of load sensitive brake equipment provides a suitable proportioned braking force over a wide variation in car weight. True variable load would hold a virtually uniform braking ratio regardless of car weight. Load compensating equipment holds uniform braking ratio through a wide part of the weight range. See Figure 139. Limited application of load compensating in service has shown this will work satisfactorily. Load compensating equipment is for a car that would normally carry vastly different types of lading with widely different weights. The term variable load as most often used in mass transit service is in reality a variable pressure limiting equipment in which the maximum brake cylinder pressure allowed is varied with car weight. This function is easily obtained since most mass transit cars use air springs in which the air spring pressure is a good measure of the car loading.

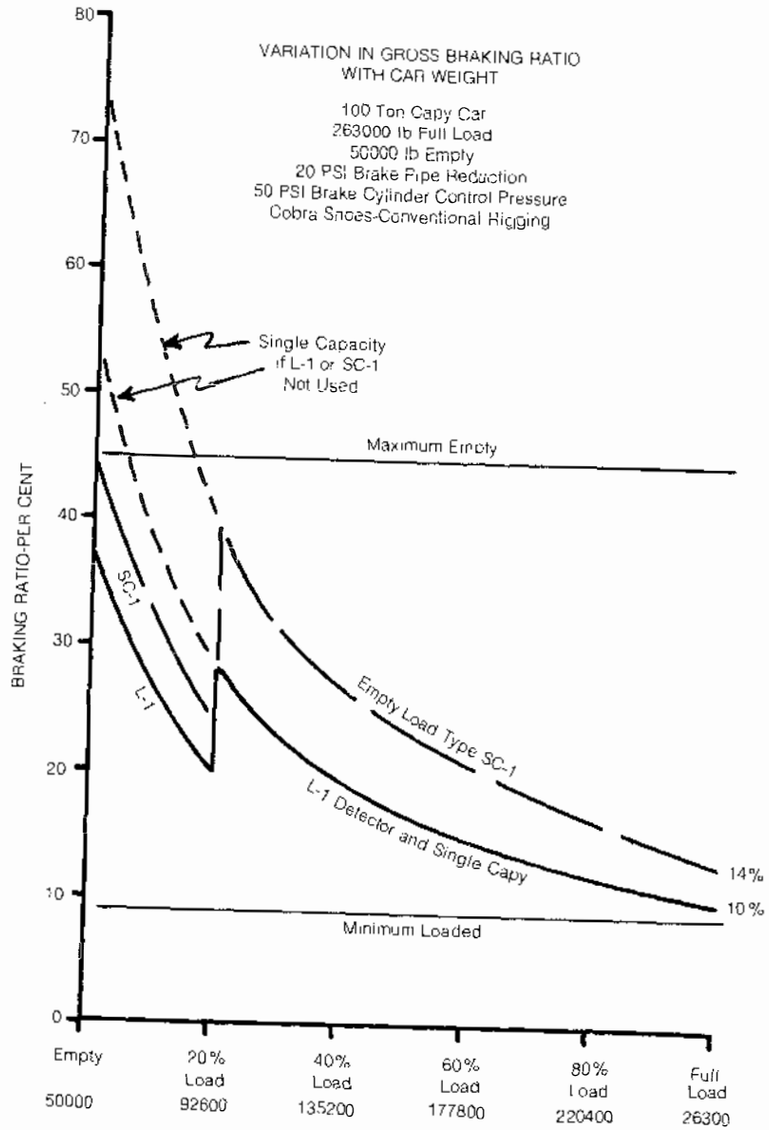


FIG. 138

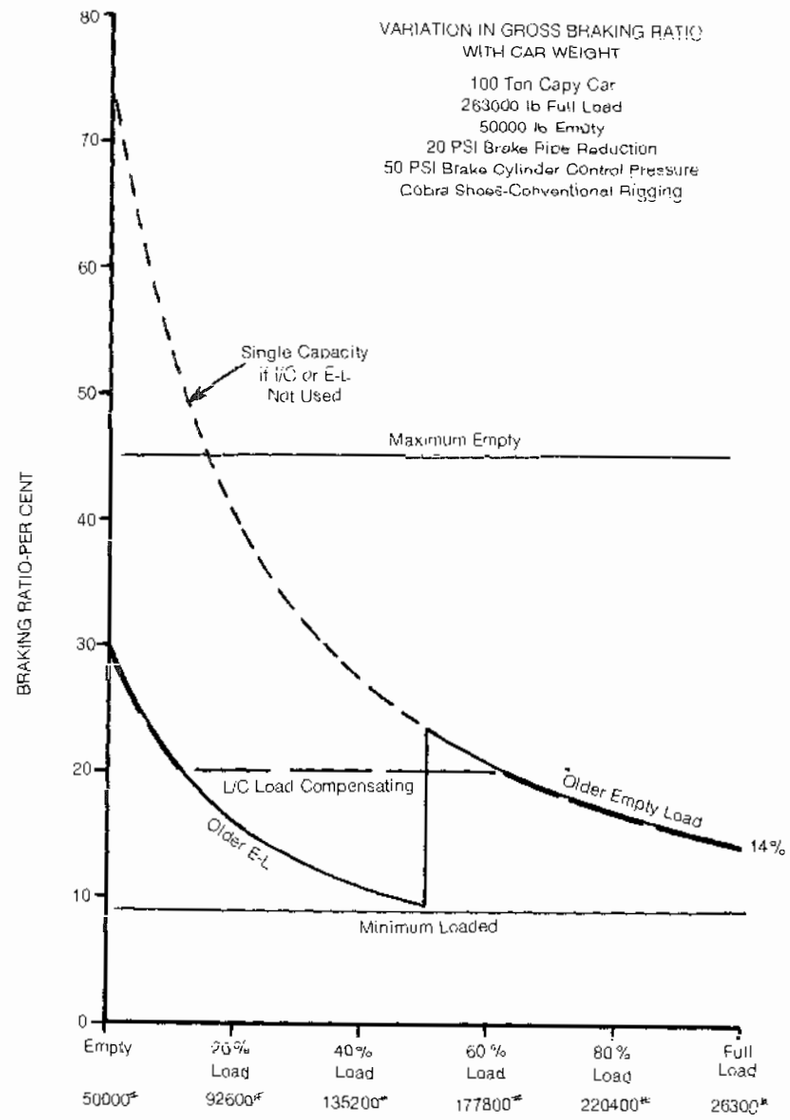


FIG. 139

Figures 138 and 139 graphically illustrate the change in braking ratio on a 100 ton capacity freight car as the total car weight changes. The relationship of Single Capacity, L-1 Detector, Empty-load, and Load Compensating equipment is shown with a 20 psi brake pipe reduction in effect which normally produces 50 psi brake cylinder or control pressure. Figure 135 shows braking ratios at various degrees of car loading with newer L-1 Detector and SC-1 Empty and Load Equipment. Figure 136 illustrates the braking ratio variation with different car weights for older Empty and Load, as well as, the Load Compensating Equipments.

SECTION 4. TRACTIVE WHEEL-RAIL ADHESION

The subject of adhesion between locomotive wheels and rails is an area that is receiving increased attention due to the significant increase in locomotive horsepower during the past decade. U. S. diesel electric locomotives have increased from about 440 to 835 hp per driver axle since 1958. Curves of constant horsepower tractive effort per axle as a function of locomotive speed are shown in Fig. 140 to indicate the increase in power potential for traction.

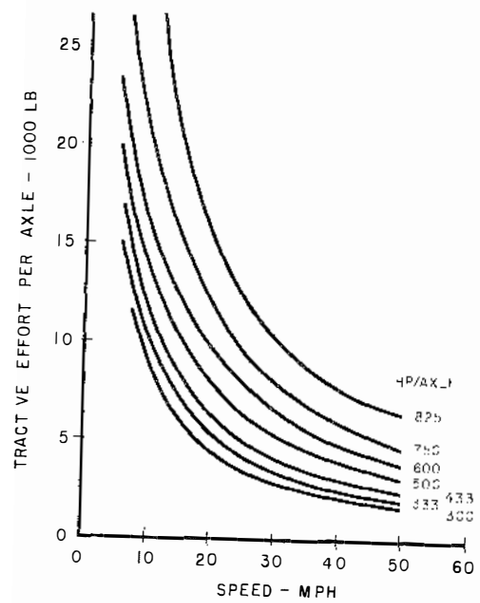


FIG. 140 TRACTIVE EFFORT PER DRIVER AXLE AS A FUNCTION OF LOCOMOTIVE SPEED

The trend for increases in horsepower per axle for EMD locomotives is shown in Fig. 141.

At the higher speed range, the higher horsepower can be utilized by longer and faster trains without serious problems due to adhesion limitations with an effective system to control slips resulting from the gross rail irregularities occasionally occurring. However, at speeds below about 25 mph, the tractive effort capability is higher than available adhesion on typical unsanded rail; and, therefore, wheel-to-rail adhesion has been a limiting factor to the usable horsepower of locomotives.

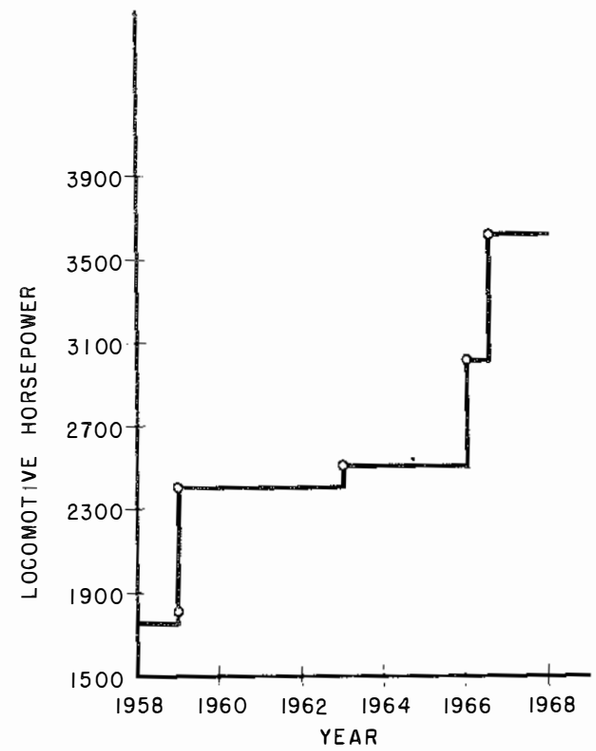


FIG. 141 TREND OF RATED HORSEPOWER FOR EMD LOCOMOTIVES DURING THE PAST DECADE

Factors Affecting Adhesion are:

I. Vehicle Factors
   1. Locomotive weight and axle load distribution on driver axles
   2. Weight transfer due to traction and geometry of locomotive body and truck components
   3. Speed
   4. Wheel size variations due to wear
   5. Electrical transmission and distribution

II. Track Factors
   6. Rail surface condition
   7. Rail profile—vertical irregularities
   8. Track curvature—tangent or curved track

III. Contact-Area Common Factors
   9. Wheel-rail materials
   10. Hertz stress
   11. Relative slip

Rail Surface Condition

Of all the factors that affect adhesion, the rail crown surface contamination is in a class by itself. The biggest influencing factor is surface contamination by oil and dirt, which are commonly accepted constituents on the track. Water and sand represent the two other most prevalent constituents. Sand is commonly used to partially remove the effect of oil and dirt and restore a reasonable friction level to correct wheel slip and to support higher adhesion requirements at certain track locations or in starting a train. In regard to water, drizzling rain depositing small amounts of water on a rail contaminated with oil and dirt will reduce the friction coefficient further. Heavy rain can, on the other hand, partially clean the rail surface and improve the available adhesion.

Fig. 147 shows curves of available adhesion as a function of locomotive speed for jointed rail on tangent track.

These curves which cover four typical track conditions on a railroad, represent the maximum adhesion levels that can be attained without the occurrence of wheel slips, and illustrate the spread of wheel-rail adhesion coefficients that exist on the railroad for straight track.

Referring to Fig. 142, the lower two curves represent the available adhesion on poor jointed rail which is moderately contaminated with oil and dirt for dry and wet surface conditions. The wet surface condition reflects the presence of rain water to the extent that no cleaning action took place on the rail surface. This condition is defined as such to differentiate it from the case where severe rainstorms clean the rail surface to the extent of improving wheel-rail adhesion to a level above the dry rail condition.

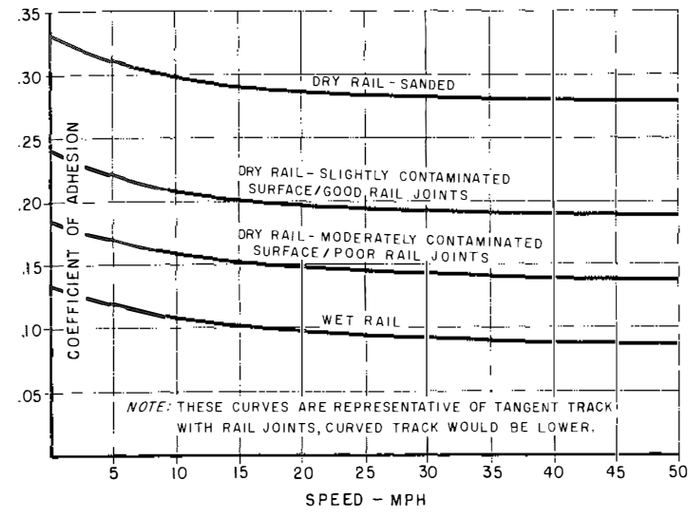


FIG. 142 DEVELOPED AVAILABLE ADHESION VERSUS SPEED CURVES FOR TYPICAL JOINTED RAIL TRACK AND RAIL SURFACE CONDITION

The higher two curves in Fig. 142 are for dry and dry sanded rails which are slightly contaminated (or relatively clean) with reasonably good rail joints. In addition to reflecting the adhesion characteristics for the specific rail condition, the dry rail curve (2nd from the top) is a reasonable approximation for use by U. S. railroads in determining drag service train loads for diesel electric road locomotives equipped with conventional 2 or 3 axle truck designs, where the track involved is relatively straight and where wheel slip control and sanding can correct slips due to infrequent gross rail irregularities. Current common railroad practice for tonnage ratings is based on 0.18 to 0.21 adhesion coefficient, developed at the lower speed and continuous current rating, which can be obtained in service operation with the occasional occurrence and correction of wheel slip.

Average and True Adhesion

Adhesion data has been reported in two forms as a function of speed: "Average Adhesion or Effective Adhesion", and "True Adhesion", as limited by wheel-rail friction. Average adhesion is the maximum total tractive effort the rail can support divided by the total locomotive weight.

True adhesion is the maximum tractive effort the rail can support on the lightest driver axle divided by that axle load. True adhesion is a corrected value for vertical load variations resulting from weight transfer due to traction; however, this value is not corrected for another factor which influences adhesion in the same indirect manner, that is vertical rail profile.

Fig. 143 compares a true adhesion curve to an average adhesion curve.

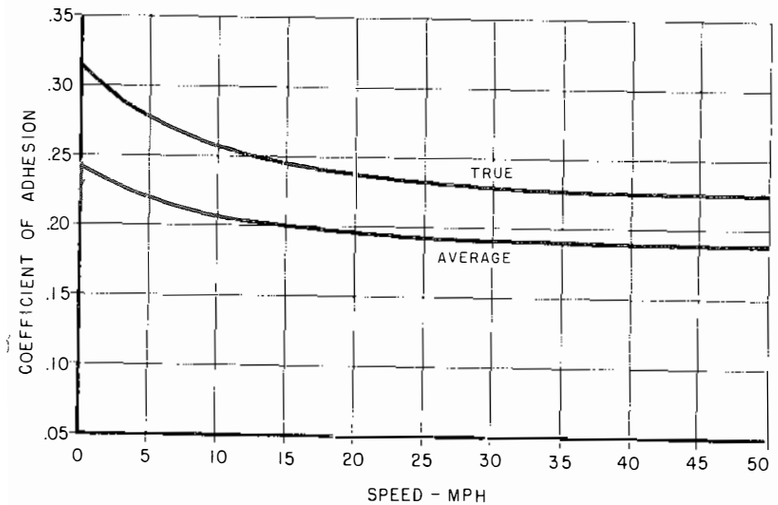


FIG. 143 COMPARISON OF AVERAGE (EFFECTIVE) AND TRUE AVAILABLE ADHESION VERSUS SPEED FOR AN SD-45 LOCOMOTIVE ON A TYPICAL DRY RAIL WITH SLIGHT RAIL SURFACE CONTAMINATION AND GOOD RAIL JOINTS

The curves shown are for dry jointed rail with slight oil and dirt contamination and for good rail joints. The interest in the true adhesion curve is more academic than otherwise; however, the two curves do indicate the influence of axle load variations due to locomotive arrangement weight transfer. This can be compared to the influence of jointed rail track profile on available wheel-rail adhesion. For example, at 15 MPH, while the adhesion loss due to locomotive weight transfer is 12 percent, the loss due to track profile is also 12 percent. Together these two factors constitute a considerable amount of tractive effort.

Speed and Rail Profile

There are two aspects of speed which affect adhesion, (a) dynamic effect on the friction-creep relationship and (b) the dynamic effect of speed on the wheel load due to vertical track profile.

The adhesion limit drops off only a small amount with speed when running on relatively poor condition welded rail. It is altogether conceivable that the loss on good condition welded rail would be hard to detect. It is true, however, that losses of adhesion are higher on poor condition jointed rail. The adhesion limit on jointed rail drops as speed increases, to about 75 percent of its maximum value before it begins to level off.

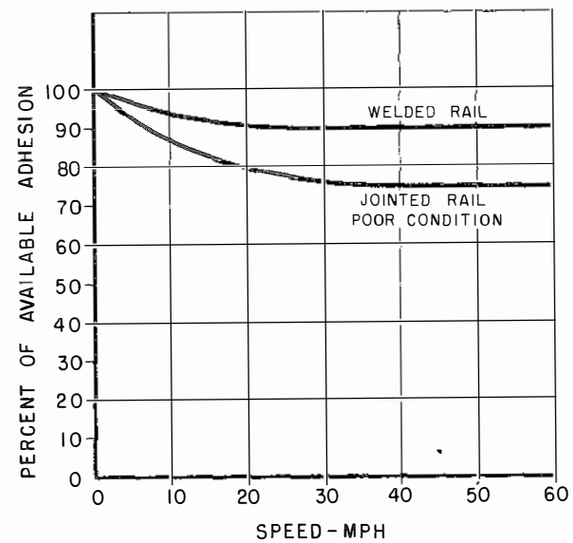


FIG. 144 AVAILABLE ADHESION LOSSES AS A FUNCTION OF SPEED FOR TYPICAL JOINTED AND WELDED RAIL TRACK

The curves in Fig. 144 show the percentage losses in available adhesion as a function of speed for jointed and welded rail. The major influence here for the jointed rail condition is the dynamic effect of speed on axle load variation due to vertical track profile. For the welded rail condition, the influence is very likely more equally shared by the dynamic effects of speed on the friction creep behavior and on axle load variations due to vertical rail profile. Fig. 141 shows the improvement in tractive effort that can be obtained by changing from jointed to welded rail.

There are, of course, other advantages such as improvement in tracking characteristics and reduced component wear and maintenance. For example, referring to curve data at 15 MPH as representing drag service operation with present locomotives, 12 percent higher tractive effort can be developed on welded rail than on jointed rail. At the higher speeds, assuming that the locomotive horsepower continues to follow the trend of the past decade and the tractive effort capability approaches the available wheel-rail adhesion, then the welded rail can support about 20 percent higher tractive effort than the jointed rail.

This points out that good maintenance of jointed rail right-of-way can contribute significant improvement in available adhesion. This is of particular importance where high adhesion demands are required.

Weight Transfer

Weight transfer is the commonly used term which refers to the redistribution of axle load due to traction and the reactions resulting on the locomotive body and truck arrangement. The ability of a truck or locomotive arrangement to minimize weight transfer under traction is measured in terms of adhesion efficiency, being equal to the ratio of minimum axle load for a specific tractive effort to the nominal static axle load.

Fig. 145 illustrates the weight shift of a standard SD-45 locomotive. The standard SD-45 locomotive is arranged so that the lightest axle is in the No. 4 position and therefore it is not exposed to virgin rail. The relationship of axle position to anticipated axle load, from lightest to the heaviest, is as follows: 4, 1, 2, 5, 6 and 3. The nominal weight of the No. 4 axle is reduced by an amount equal to 14 percent of the locomotive tractive effort, the No. 1 by 8 percent and the No. 2 by 6 percent (Fig. 6).

This means that at 50,000 lb. TE the No. 4 axle load of a 402,000 lb. locomotive (SD-45) is 60,000 lb. instead of its nominal 67,000 lb. At 100,000 lb. TE the same axle weighs only 53,000 lb.

On the other hand the No. 3 axle, which becomes the heaviest, weighs 74,000 lb. and 81,000 lb. at 50,000 lb. and 100,000 lb. TE, respectively. This gives rise to higher wheel, axle and rail stresses.

The No. 4 and No. 1 axles are the most prone to slip. The fact that the No. 1 axle is always exposed to virgin rail (on a lead locomotive) increases its susceptibility to slip, especially on straight track and at higher speeds. The effect of the virgin rail makes the No. 1 axle comparable to the No. 4 axle even though it has less tractive weight shift. It should be mentioned that on a trailing locomotive the rails are conditioned by the leading units, and the No. 1 axle becomes more stable, with the result that the No. 4 axle slips most frequently.

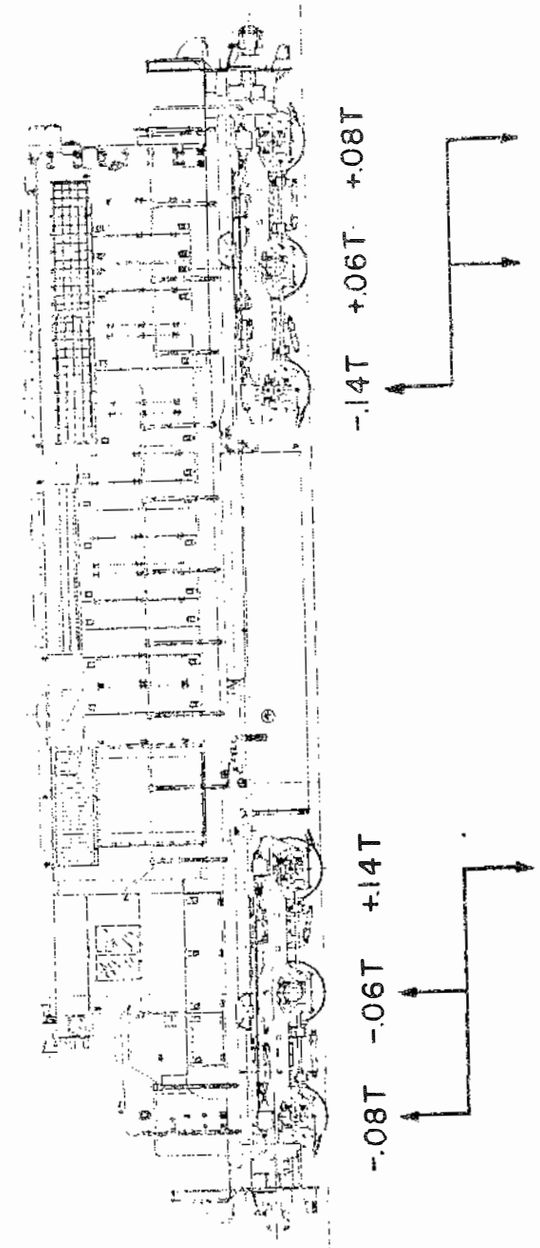


FIG. 145 WEIGHT SHIFT OF A STANDARD SD-45 LOCOMOTIVE, WHERE T IS THE TRACTIVE EFFORT

Track Curvature

Track curvature is also a major influence on adhesion. Tests have shown up to a 50 percent loss of adhesion while negotiating a 4 degree curve on welded rail. While sanding will increase the adhesion in a curve, it has severe effects upon wheel and rail wear because of the lateral forces associated with curve negotiation which also increase as the wheel-to-rail adhesion increases.

SECTION 5. IDAC WHEEL SLIP CONTROL SYSTEM

The name "IDAC" is made up from the first letters of words that describe the wheel slip control system. These words are, "Instantaneous Detection And Correction."

Extensive and intensive experimentation and testing, both in the laboratory and on locomotives pulling freight, has provided evidence that wheel slip correction is best accomplished by a very sharp decrease in power limited in proportion to the severity of the slip. Reapplication of power after a slip is corrected should be initially fast, followed by a leveling off near the power level at which the slip occurred.

The IDAC wheel slip control system performs the aforementioned action and retains the versatility of the transductor type wheel slip detection system. The transductors require a minimum of maintenance and are not susceptible to mechanical damage. They have good detection sensitivity and offer built-in protection against motor overload and underload or switchgear defect. Defective shunting resistors or improper wiring can also be detected by the transductors.

Six axle locomotives in the 40 or 45 series are equipped with three wheel slip transductors, and four axle locomotives in the 40 series are equipped with four transductors. The outputs from all transductors on a locomotive are connected in parallel and loaded on a single 35 ohm resistor.

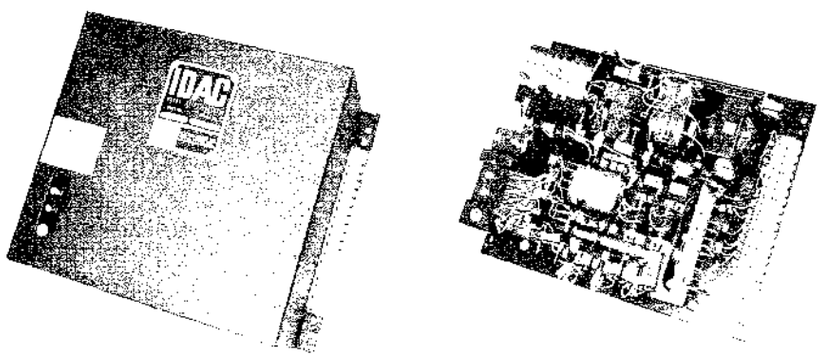


FIG. 146 IDAC WHEEL SLIP CONTROL SYSTEM — WSC PANEL ASSEMBLY

The voltage drop across the resistor provides the wheel slip signal. The signal is the sum of transductor outputs, it initiates corrective action.

In addition to the through-cable transductors, IDAC uses bridge-connected voltage sensitive relays to detect wheel slide during dynamic braking, and on SD locomotives uses the relays as a backup for the transductors during series-parallel power operation. Except for the transductors, the voltage relays, a time delay sanding relay, and a wheel slip light relay and light, the components of IDAC are enclosed in a metal box of about one-half foot cube, Fig. 146. The box is mounted within the main electrical cabinet of the locomotive, and is identified on the locomotive schematic wiring diagram as wheel slip control WSC. Its components require no field adjustment or calibration.

IDAC is equipped with a test pushbutton plus red and green indicating lights. With the engine running and the throttle in idle position, the red light comes on when the test pushbutton is pressed and held to inject a 75 V AC simulated wheel slip signal into IDAC. After a moment the red light will go out and the green light will come on, along with the white wheel slip light on the control stand. The green light indicates with a high degree of probability that all IDAC components are functioning properly.

NOTE: Sanding will occur when the test pushbutton is pressed, unless the sanding magnet valves are disabled.

The primary wheel slip detection devices — the transductors — remain unchanged from earlier systems, but application of the wheel slip signal from the transductors differs. With IDAC, normal wheel slip correction results from a *change* in the strength of the signal from the transductors, rather than from the *level* of signal strength. The degree of correction is dependent upon the rate at which an increase in signal strength takes place. IDAC, however, responds in a protective manner when a severe slip results in signal strength of a high level.

The use of a change in signal strength rather than a level of signal strength overcomes the effects of normal differences in transductor output from one locomotive to another. The differences result from normal manufacturing tolerances and from conditions of wear and use. On earlier systems, these differences make necessary the use of slip signals at a high average level in order to ignore false signals. This prevents corrective response at the lowest levels of wheel slip.

With the IDAC system, the normal level of transductor output is irrelevant, since with the exception of severe motor unbalance, it is a change from the normal level that is used to signal slips. The *rate* at which an increase to above normal takes place controls the degree of corrective response.

The change in signal strength from the transductors is seen at an RC circuit (resistor-capacitor) that in effect converts the rate of increase into a usable value that is dependent upon *rate of increase.* Power re-

duction is then made in direct proportion to that usable value. Thus, power reduction does not take place in relation to the speed of slipping wheels, but in relation to the rate of speed increase or acceleration of those wheels.

The stages of power reduction are as follows:

1. *First Stage—Sharp Power Reduction*

   Small and instantaneous reduction of power will correct most wheel slips, and immediate reapplication of full power after a minor slip is corrected prevent unneeded power reduction. IDAC provides the desired action by instantaneously lowering the load regulator reference signal (without moving the rheostat brush arm) to the main generator excitation system whenever a slip is detected. When the slip is corrected, the load regulator reference signal and locomotive power are immediately restored.

   Under conditions of heavy drag and poor adhesion where repetitive slips are encountered, IDAC will maintain locomotive power at the optimum level for conditions. Train handling is smooth, and power reduction by the operator is not required.

   In this first stage the amount that the load regulator reference signal is lowered is in direct relationship to the acceleration of the slipping wheels. If the slip or slide is detected by bridge-connected voltage relays (during dynamic braking), the load regulator signal is also lowered a specific amount.

   In addition to correcting differential slips before severe loss of adhesion occurs, the instantaneous response of IDAC greatly reduces the chances of simultaneous slip. If a simultaneous slip does occur it is detected by pickup of the overvoltage relay OVR or by forward transition relay FTR after the last step of motor field shunting. Correction is accomplished by dropout of the generator field relay GF in such rare and extreme cases.

2. *Second Stage—Modulation of Power*

   When the signal bringing about the action in the first step exceeds a predetermined value, second stage circuitry operates to apply sand to the wheels and to bring about discharge of the rate control panel RCP capacitors at a controlled fast rate. The rate of discharge varies with the step of transition or motor field shunt depending upon the type of locomotive.

   Generator excitation is reduced as the capacitors discharge through predtermined values of electrical resistance. When the slip is corrected, the capacitors are recharged at the rate inherent in the power control system, and generator excitation is increased to reapply power smoothly. Sanding continues for a timed period after slip correction.

3. *Third Stage—Steady State Pickup*

   If the output from the transductors reaches a predetermined high level, third stage circuitry is actuated. Action of this stage is dependent upon signal strength only, not upon the rate of increase in signal strength. The third stage backs up the action of the second stage in that the corrective action it provides is the same as that provided by the second stage. However, a steady signal with little rate of increase will actuate the third stage, and protection against slowly progressing high speed slips or against faults such as locked-sliding wheels is ensured.

SECTION 6. SANDING

Diesel electric locomotives of recent design are equipped with two manual sanding switches in the locomotive cab: a lead truck sanding switch, which initiates sanding only at the leading axle of the leading unit in a locomotive consist, and a manual sanding switch which initiates sanding at the leading axle of each truck in the consist.

Sanding is automatically initiated during wheel slip and may also be initiated by emergency brake applications.

Figure No. 147 shows the Salem electric sanding system. When in the on position the lead truck sanding switch 1 allows an electrical signal to flow to the #1 truck forward sanding control valve 2, which when energized allows main reservoir air to flow to the #1 truck forward sand traps 3 which deliver sand in front of the #1 axle. Diode 4 prevents #2 truck forward sander control valve 5 becoming energized. During a lead truck sanding application the indicating lamp 6 in the control stand is lit. The use of lead truck sanding should be strongly encouraged since in most situations it provides the necessary adhesion while markedly reducing the costly adverse effects excessive sanding has on track, roadbed, and equipment.

When in the on position the manual sanding switch 7 allows an electrical signal to flow through the reverser contacts 8 to the forward sander control valves 2, 5, or to the reverser sander control valves 9, 10 on both trucks. An electrical signal is also fed into the trainline wire, so as to initiate sanding on trailing units. On units having to multiple with older units, having only a pneumatic sand trainline, this signal is also fed through the reverser interlocks 11 to the forward sander relay valve 12, or to the reverse sander relay valve 13 depending upon the position of the reverser 11. The sander relay valve 12 or 13 when energized sends

TYPE I ELECTRIC SANDING

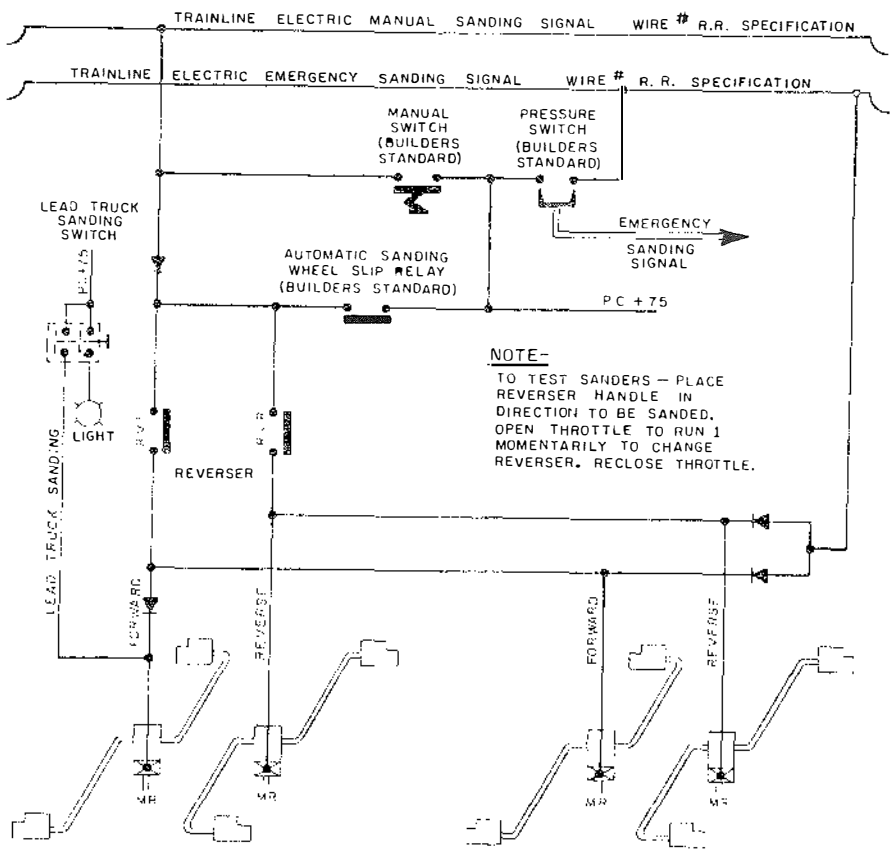


FIG. 147

an air signal through the pneumatic sand trainline to initiate sanding on trailing units equipped with pneumatic sand trainline. Forward sanding pressure switch 14 and reverse sanding pressure switch 15 are utilized to receive a pneumatic sanding signal when trailing older units equipped with pneumatic trainline sanding. Upon receiving a pneumatic sanding signal, the contacts in pressure switch 14 or 15 close, thereby energizing sander control valves 2, 5, or 9, 10 and initiating sanding.

The TDS contacts 16 are picked up by the wheel slip relay and sanding is instigated in the same manner as from the manual sanding switch 7 except that diode 17 prevents the signal from being trainlined, thereby limiting sanding to the slipping unit. The TDS relay 16 should be set to remain closed for 3-5 seconds after being de-energized, thus providing 3-5 seconds of sand.

During an emergency air brake application, air from port 9 or 35 of the A-1 charging pilot cut-off valve, or from port 12 of the 26-C brake valve (brake valve initiated emergency) flows to the emergency sand switch 18, thereby closing its contacts. This allows an electrical signal to flow through diodes 19 and 20 and energize forward sand relay valve 12 and reverse sand relay valve 13. When energized these valves allow main reservoir air pressure to flow to forward pressure sanding switch 14 and reverse pressure sanding switch 15, thereby closing their contacts and energizing all forward sand control valves 2, 5, and all reverse sand control valves 9, 10. The reason for sanding both forward and reverse traps in emergency is to insure sanding in front of the lead axle in the event motors are plugged (reverser lever placed to oppose direction of travel). Diode #21 prevents the trailing electric manual sanding wire being energized thereby protecting diodes 19 & 20 from being overloaded. The emergency pressure sand switch 18 when closed also energizes the emergency trainline wire so as to initiate emergency sanding on trailing units. The forward sand relay valve 12 and the reverse sand relay valve 13 when energized also feed main reservoir air into the forward and reverse pneumatic sand trainlines, thereby initiating emergency sanding on trailing units equipped with pneumatic sand trainline, provided hoses are connected between units.

At the beginning of the sanding cycle, the sander control valve allows main reservoir air to flow unrestricted to the sand traps for a fraction of a second. After this initial surge of charging air, metered sanding air is maintained through two orifices in the sander control valve. At the termination of the sanding cycle, main reservoir air again flows unrestricted to the sand traps for a fraction of a second, thereby providing a clean out surge.

Depressing the two clean-out plungers located on each sander control valve, cleans out the sanding orifices. Charging air at the beginning of the next sanding cycle will automatically reset the clean-out plungers.

The clean-out plungers may also be used as indicators when checking or trouble-shooting the sanding system.

The Prime electric sanding system employs a magnet valve mounted directly to each sand trap and an orifice block instead of a sand control valve. However, it is controlled in the same manner as the Salem sanding system.

Figure No. 148 shows the Prime sanding system.

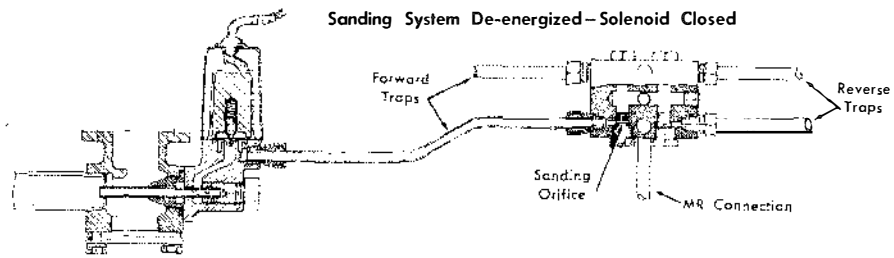


FIG. 148 SANDING SYSTEM DE-ENERGIZED—SOLENOID CLOSED

Main reservoir air flows through the sanding orifice 1 to the sanding magnet valve 2 which when not sanding is de-energized, thus bottling up main reservoir air pressure between the magnet valve 2 and orifice 1. Sanding is initiated by energizing the magnet valve 2 which allows main reservoir air bottled up between the orifice 1 and magnet valve 2 to flow to the sand trap 3. After this initial surge of charging air, metered sanding air is maintained through orifice 1.

A layer of silica sand one particle thick, is as effective as larger quantities in controlling wheel slippage. The theoretical optimum delivery rate is 1/4 lb per minute at 14 mph. However, to allow for unavoidable wastage under actual operating conditions, the sand traps are set to deliver approximately 20 to 24 oz of sand per minute.

The adjustable nozzle type sand trap, rate of sand delivery is controlled by screwing the adjusting nut at the back of the trap in or out. Screwing the air nozzle out increases sand delivery, whereas screwing it in decreases sand delivery.

The adjustable gate type sand trap, rate of sand delivery is controlled by turning the sand controller at the side of the trap. An arrow on the control unit indicates direction of rotation for increasing or decreasing sand delivery.

A sand shut-off assembly is mounted to the top of the trap at the sand inlet. The valve is in the open position when the hand level on the side is set at OPEN or is parallel to the sand inlet line. The shut-off can be used when it is desirable to have a particular sanding line inoperative, or if work is to be performed on the sand trap.

Due to condensation, there is always the possibility of getting moisture in the sand trap. To clean out the trap, remove the pipe plug at the bottom of the trap.

Sand quality is of extreme importance and care should be taken that the proper grade of clean dry sand is used. Damp or dirty sand, or sand with foreign material in it is likely to clog the traps and also provide less improved adhesion.

SECTION 7. DYNAMIC BRAKING SYSTEM

Dynamic braking is an electrical arrangement used to change some of the mechanical power developed by the momentum and downhill force of a moving train into electrical power. The electrical power is converted into heat which is blown out through a hatch at the top of the locomotive.

Traction motor armatures, being geared to the axles, rotate whenever the locomotive is moving. During dynamic braking the motors become electrical generators, and the electrical output of the motor armatures is connected across fan cooled resistor grids of fixed ohmic value. Armature output is determined by the speed at which the armatures rotate (track speed) and by the amount of excitation current flowing in the motor fields (stationary coils).

Excitation current in the motor fields is controlled by braking lever (throttle) position and by a regulating device. This device, the dynamic brake regulator DBR, senses voltage across one-half a braking grid, interprets it as armature/grid current, and operates to reduce field current in order to hold armature current (and grid voltage) at the maximum permitted by equipment design. It does this whenever maximum current level is attained, regardless of braking lever (throttle) position.

The graph in Fig. 149 shows that with maximum traction motor field current (braking lever in position 8), braking effort increases as track speed increases from zero to about 25 mph. Thereafter, braking effort lessens as track speed increases.

Braking effort may be considered as negative tractive effort or "drawbar push." This effort can be interpreted as weight, with both grade force and the momentum of the moving train going to make up what is being called weight. The weight by itself performs no function; it merely has the ability to perform useful work. During dynamic braking the use of the work is to maintain train speed or to slow down a train.

This work results in heat at the dynamic braking grids rather than at brake shoes.

To understand the term "braking effort," consider the terms:

1. Mass or weight.
2. Work—the energy required to lift the weight a given distance.
3. Power—the energy required to lift the weight a given distance in a given amount of time. For example, a very small output of energy can lift a tremendous weight if given sufficient time.

Fig. 149 indicates that braking effort falls off as train speed increases above the optimum. This is so because of design limitations in the equipment involved. Theoretically, braking effort could increase along the dash-dotted line extending to the top of the graph, but regulation occurs to protect the equipment.

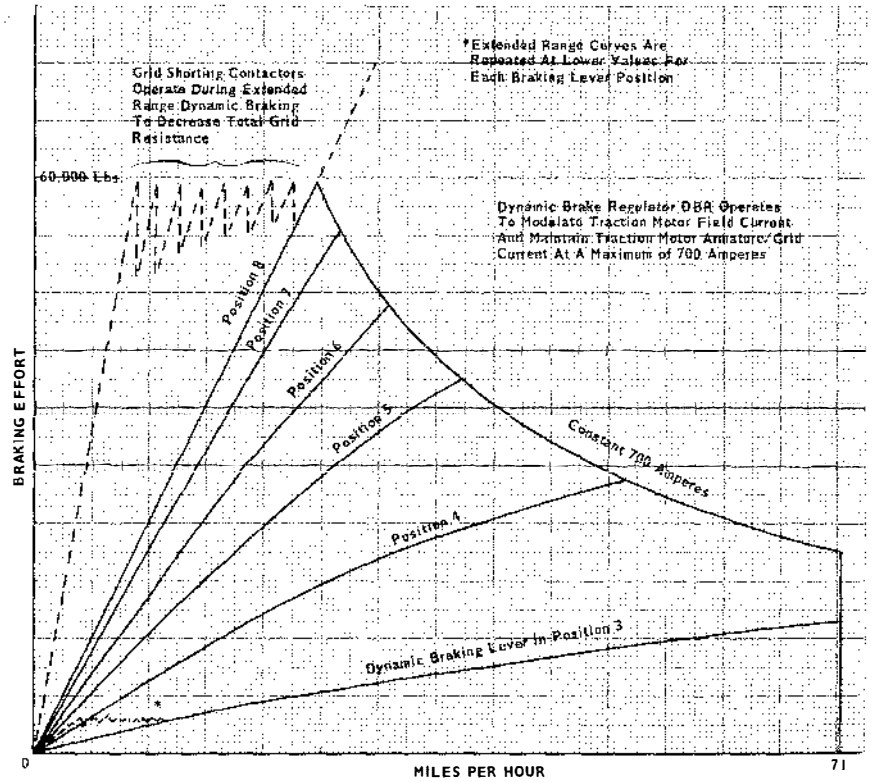


FIG. 149 DYNAMIC BRAKING CURVES—62:15 GEARING BRAKING EFFORT/MILES PER HOUR

To determine why braking effort does not remain at the maximum value, but falls with increased track speed, note the following:

1. At maximum braking lever position, grid voltage and current are regulated and constant above approximately 25 mph; consequently the power (volts × amperes) dissipated as heat is constant.
2. Power, electrically expressed as volts × amperes, may also be expressed as foot pounds per second or, in railroad terms, ton miles per hour.

$$1 \text{ Horsepower} = \frac{375 \text{ pound miles}}{\text{hour}}$$

Since design limitations require that the current in the dynamic braking resistors does not exceed maximum, an increase in the speed factor (miles/hours) of the horsepower formula must be accompanied by a decrease in the weight factor (pounds) of the formula in order to maintain the maximum current limitation. This weight factor is reduced by decreasing the retarding force of the traction motor fields.

In other words, a decrease in the magnetic flux induced by motor field current, brings about a reduction of the resistance to the turning of the motor armature. Less effort is required to turn the armature, but since it turns faster at higher track speed, the resulting power remains the same while braking effort decreases.

EXTENDED RANGE DYNAMIC BRAKES

Below optimum speed of about 25 mph, braking effort declines. This is because the voltage developed by the motor armatures falls below maximum even though motor field excitation is at its upper limit.

By Ohm's law $$I = \frac{E}{R} \text{ or}$$

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

It can be seen that when voltage drops, current can be maintained at a high level only by reducing grid resistance. The extended range dynamic braking system reduces grid resistance in steps as track speed decreases.

In the extended range dynamic braking system all resistor grids are connected in series with all motor armatures. Cables carrying dynamic braking current pass through the frames of two transductors, and coils carrying AC from the D14 alternator are wound on the cores of the transductors. The impedance of these coils is controlled by the amount

of current passing in cables through the transductor frames. The output from the AC coils passes through the primary windings of transformers and is transformed to a usable value. The output from the transformers is rectified and loaded upon resistors and potentiometers.

Voltage signals that are in direct proportion to the current in the dynamic braking cables are taken from the brush arms of the potentiometers and directed to sensitive polarized relays. The relays match the signals against throttle controlled signals and function to control stepping of a motor operated program switch that in turn controls pickup of power contactors. The power contactors, located in a hatch adjacent to the grids, close singly and in combination to short out portions of the total dynamic braking grid resistance and thus maintain maximum braking current down to very slow speed.

On SD type locomotives dynamic braking current also passes through the frame of a voltage operated current biased relay OCP that picks up to disable the dynamic braking system if an open resistor grid results in voltage at the relay coil but no current in the system.

SECTION 8. RADIO CONTROL OF LOCOMOTIVE

OPERATION RECOMMENDATIONS

These recommendations cover the following five areas:

(1) Operating instructions.
(2) Train air tests.
(3) Methods of conditioning units.
(4) Instructions on the use of equipment in the failure of radio controlled units.
(5) Qualifying procedures (training).

When the term RCE-1 is used, it refers to either the lead equipment, remote equipment, or both, for remote radio control of locomotive unit(s) and train.

Procedures outlined do not supersede any requirements of the Power Brake Law, and are to be considered minimum requirements.

1. OPERATING INSTRUCTIONS
   A. Before leaving shop, service or parking track with the control (lead) locomotive, radio equipment on RCE-1 must be conditioned as follows:
      1. All radio control power switches in *OFF* position.
      2. All control console switches in *OFF* or *OUT* position.
      3. The control console selector switch in *ISOLATE* position.

      4. *CAUTION:* On remote controlled units, RCE-1 equipment must be conditioned as may be necessary to prevent unintentional movement.
   B. After control locomotive and remote controlled units are coupled to train, condition control locomotive as follows:
      1. Place automatic brake valve in release position.
      2. Place all radio control power switches in *ON* position.
      3. Place console power switch in *ON* position if so equipped.
      4. When remote controlled car or locomotive is conditioned for service and continuity established, feed valve can be cut in on the remote controlled car or locomotive.
2. TRAIN BRAKE TESTS
   A. Initial Terminal Brake Test.
      1. Make a 15 lb. service brake pipe reduction using air brake console.
      2. Cut out feed valves on both control locomotive and remote controlled car or locomotive.
      3. Make brake pipe leakage test.
      4. Increase brake pipe reduction to full service and perform train air brake inspection for application of brakes as required.
      5. Start the air brake release by cutting in only 1 feed valve, either on control locomotive or on remote unit.
         a. If the feed valve on the control locomotive is cut in for the release test, the feed valve on the remote control unit must not be cut in until it is known that brake pipe pressure at rear of freight train has *increased significantly.*
         b. If the feed valve on the remote unit is cut in for the release test, the feed valve on the control locomotive must not be cut in until the brake pipe pressure on the control locomotive shows a *significant increase.*
      6. Before proceeding it must be known that the brake pipe pressure, as indicated at the rear of the freight train, is being restored and that all requirements of an initial terminal air brake test has been complied with.
   B. Train Brake Tests Other Than At Initial Terminal
      1. Make a 20 lb. service brake pipe reduction using the air brake console and determine that brake on rear car applies.
      2. Start the air brake release by cutting in control (lead) locomotive feed valve only. The feed valve on the remote control unit must not be cut in until it is known that brake pipe pressure at the rear of the freight train has *increased significantly* and it is determined that brake on rear car releases.

3. METHOD OF CONDITIONING UNITS

A. When Cutting Off Controlling Unit or When Picking Up or Setting Out Cars.

1. Cut out remote consist feed valve.
2. Isolate remote consist.
3. After separation, the angle cock must be left open, at cut, on the portion of the train left standing.
4. When picking up cars, the angle cocks at each separation or cut, must be checked to insure that they are in their open position as required by Power Brake Law.

B. Shutting Down RCE-1 Radio Equipment

1. Place all switches on the control console in *OFF* or *OUT* position.
2. Place console selector switch in *ISOLATE* position.
3. Place all radio control power switches in *OFF* position.
4. *CAUTION:* On remote controlled units, RCE-1 equipment must be conditioned as may be necessary to prevent unintentional movement.

C. In the Event of RCE-1 Equipment Failure

In the event of failure with Radio Control Equipment which renders operation as a radio train unsafe, RCE-1 equipment will be shut down and train operated in conventional manner.

5. QUALIFYING ENGINEERS ON THE OPERATION OF RCE-1 RADIO CONTROL EQUIPMENT (TRAINING)

To qualify for this type service, an engineer must first be qualified for conventional train operation, and type of locomotive from which radio control equipment will be operated.

The Carrier has the prerogative to qualify engineers on items listed in this procedure by (1) classroom instruction; (2) on-the-job supervised training; or (3) any combination of (1) and (2). Written record must be maintained showing engineer's name, qualifying officer's name, and date of qualification.

In order to qualify, engineer must demonstrate a thorough understanding of the following:

I. Principle of Radio Control Operation Compared to Conventional operation: Locomotive consist is made up of the head end locomotive unit(s) and additional unit(s) located in the train. Units located in the train, herein referred to as "remote consist," are controlled by radio signals in lieu of electrical jumper cables and pneumatic air hoses.

The engineer has control of the remote consist. This control includes charging, applying and releasing train brakes, applying and releasing independent brake, and operation of the throttle in all power and in dynamic brake positions.

II. Operation of Equipment:

A. Continuity

1. Continuity is the radio communication between controlling unit and remote consist.
2. Procedure that must be followed to safely establish continuity when radio equipment on the controlling unit is turned on.
3. How remote consist is controlled by engineer during continuity operation.
4. Recognizing a continuity search period.
5. Recognizing loss of continuity (no continuity).
6. How remote consist responds when loss of continuity occurs.
7. How remote consist responds when continuity is re-established.
8. Purpose of override system.
9. Controlling remote consist during a no continuity override operation.

B. Remote Automatic Brake Operation:

1. Cutting in remote automatic brake equipment.
2. Charging, applying and releasing train brakes using remote automatic brake equipment.
3. The different conditions that will automatically cut out the remote automatic brake equipment.
4. Manually cutting out remote automatic brake equipment.
5. How automatic brake equipment on controlling and remote units can be used independently or as a unit.
6. How an emergency brake application functions from the air brake console on the controlling unit.

C. Independent Brake Operation:

1. Operation of independent brake on remote units from air brake console on controlling unit.

D. Wheel Slip System:

1. Recognizing and correcting a wheel slip or slide on remote consist.

E. Penalty Application:

1. Remote unit response to a penalty application, and reset procedure.

F. Power Cut Off (PC) Operation:

1. Remote unit response when power cut off circuit (PC switch) is tripped, and reset procedure.

G. Power and Dynamic Brake:

1. Controlling power and dynamic brake on remote consist.

2. Recognizing amount of power or dynamic brake being developed on remote consist.

III. Procedures for Handling Locomotives and Trains with RCE-1 Radio Control Equipment:

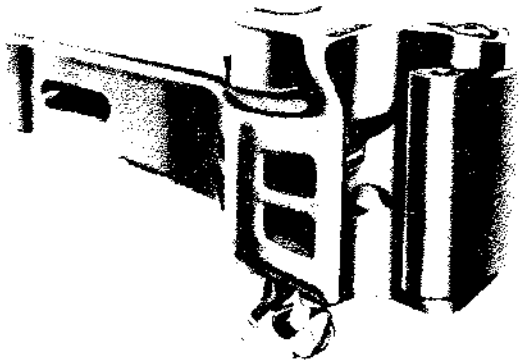
1. Proper position of RCE-1 switches on controlling unit before leaving shop, service, or parking track.
2. Turning on RCE-1 switches after control locomotive and remote consist are coupled to train.
3. Making air brake tests.
4. Making set-offs or pick-ups ahead of the remote consist.
5. No continuity operation.
6. No continuity override operation.
7. Emergency brake application occurrence.
8. RCE-1 equipment failure.
9. Proper position of RCE-1 switches on controlling unit when shutting down equipment.

SECTION 9. COUPLER FAILURES

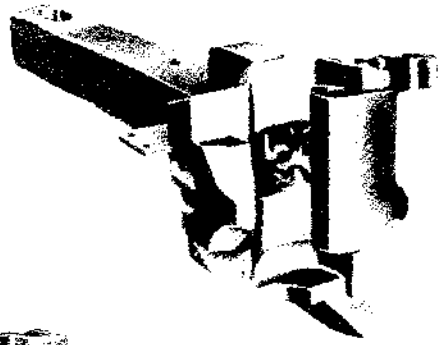
Replacement

Because of the many different types of couplers in use in freight trains it is of advantage to the trainmen to be able to distinguish between the various knuckles used with these couplers. The AAR Standard "E" Coupler, with either a rigid, swivel, or Type "F" shank is used on most freight cars at the present time. These couplers can be identified by the letter "E" *immediately preceding the two numbers*, which appear in the catalog number cast into the top of the coupler on the guard arm side. Typical type "E" coupler designations are B-E60B-HT, B-E16B-HT, E67A-HT, E68A-HT, and E69-HTE, etc. dependent upon the type and size of the shank or type of draft gear arrangement it is used with. The catalog designation of the knuckle used with the Type "E" Coupler, which is cast into the top of the knuckle, is E50-HT. The letters "HT" designate that the knuckle was cast in high tensile steel.

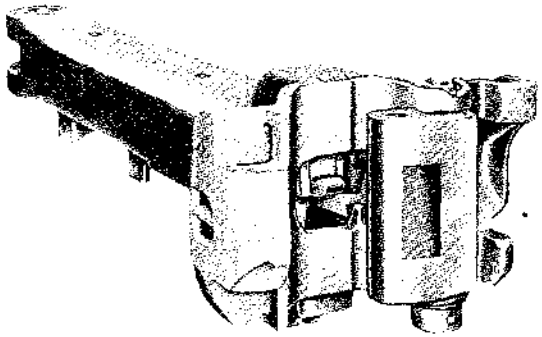
There is a tendency toward greater use of the AAR Alternate Standard Type E/F and Type "F" Interlocking Coupler especially on TTX equipment and also on integral unit trains where the Type F rotary coupler permits car dumping without uncoupling or disconnecting air hoses. These couplers can be identified by the letter "F" immediately *preceding the two numbers* which appear in the catalog number. On Type "F" Coupler bodies the catalog number is cast into the top of the coupler on the knuckle side. Typical Type "F" coupler designations are F70B-HT, F79B-HT and F73-HT. The catalog designations of the knuckle used with the Type "F" Coupler is F51-HT. Thus any coupler knuckle with the letter "F" can be used with any coupler body that includes the letter



TYPE E



TYPE F



TYPE H

FIG. 150

"F" as part of its catalog number as shown in the examples above.

Also with the greater use of mixed trains, that is trains carrying freight cars and head-end express cars, or a combination of freight and passenger cars, it is important for the trainman to be able to also identify the knuckle used with the AAR Standard "H" Tightlock Coupler. The Type "H" Couplers can be identified by the letter "H" immediately preceding the two numbers which form a part of its catalog number. The catalog number of the knuckle used is H50-HT-5. It can be seen from the above discussion that any coupler knuckle with the letter E, F or H can be used with coupler bodies that include the same letters in their catalog numbers. The letter designating the coupler type will be that letter *immediately preceding the two numbers* forming part of the catalog number. For reference the attached sketch shows the location of the catalog numbers which are cast into the coupler bodies and knuckles by the various manufacturers. In the case of the coupler body its catalog number will appear on the top of the coupler on either the guard arm or knuckle side as shown in the sketch. In the case of the knuckle its catalog number will appear on the top side as shown. In those cases where the catalog number of the knuckle is not discernible due to weathering or other reasons the proper knuckle replacement can be determined by noting the letter designation on the coupler body as discussed previously.

It is recommended that Type "E", F and H knuckles be carried in the caboose for emergency replacement for use where knuckle failures occur.

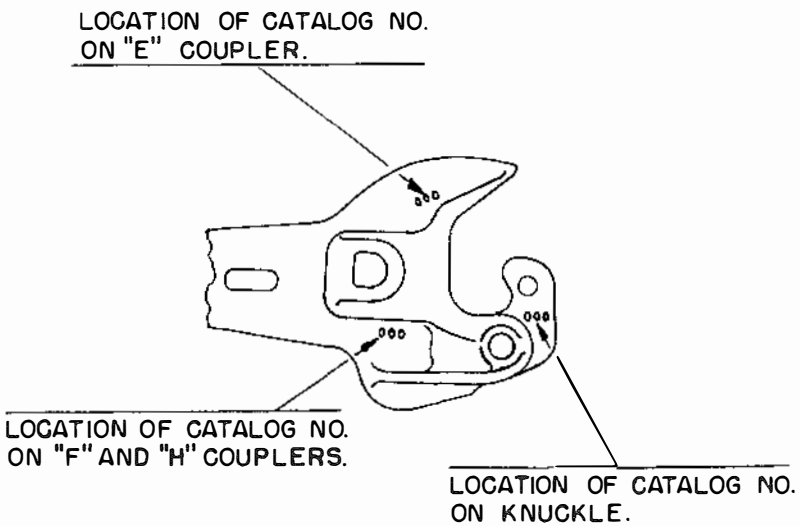


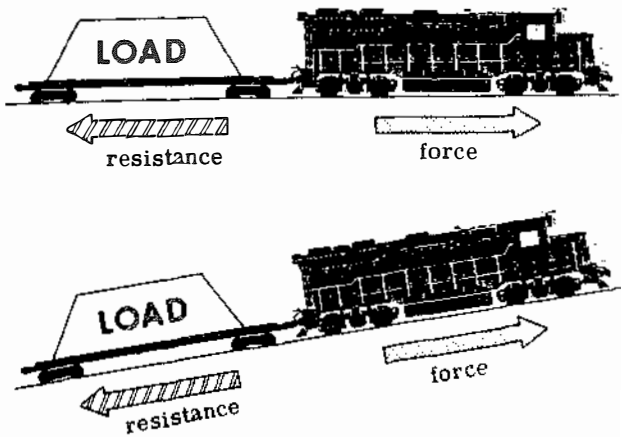
FIG. 151

When a knuckle on an open top car is replaced and no replacement cotter key is available for the knuckle pin, the car department should be notified so that the cotter key can be applied at the first opportunity.

SECTION 10. TRAIN RESISTANCE

Resistance: Any opposing or retarding force.

Force: The cause of the acceleration of the movement of physical bodies.



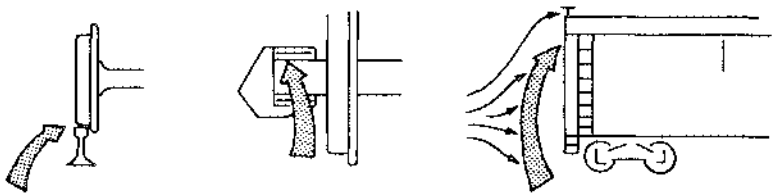
In all cases where the force exceeds the resistance, the load will be accelerated.

As acceleration continues, i.e., as speed increases, the force will diminish and the resistance increases until they are equal. At this point a "balance speed" is obtained.

All locomotive performance calculations are, in effect, nothing more than a process of equating force and resistance under a given set of conditions.

ROLLING RESISTANCE

The rolling resistance of a train can be determined by formula, but more generally is taken from tables and curves based on formula. The most widely used of such formulae is the Davis Formula. Rolling resistance is generally expressed in pounds per ton.



Flange Resistance + Journal Resistance + Air Resistance =
Total Rolling Resistance

Other things being equal, total rolling resistance, expressed in pounds per ton . . .

1. ...Increases as speeds increase
2. ...Decreases as car weights increase

ROLLING RESISTANCE
(Lb./Ton)

Speed	20 Ton Car	100 Ton Car
10 MPH	7.5	2.6
60 MPH	16.5	7.0

(Note, however, that when expressed in total pounds, the 100-ton car naturally offers more resistance than the 20-ton car.)

DAVIS FORMULA for rolling resistances:

The rolling resistance of locomotives and cars is affected by so many variable factors (weight, speed, size, journal type, configuration, wind, temperature, etc.) that it can be accurately determined only by test. Obviously performance calculations must rely on something more practicable. The most widely known and universally accepted of the several formulae for calculating resistance of a given train is the one developed by W. J. Davis.

$$R = 1.3 + \frac{29}{W} + 0.045^{*}V + \frac{0.0005^{*}AV^2}{Wn}$$

where: R = resistance in lbs./ton on level tangent track
W = weight per axle in tons
n = number of axles per car
A = cross section of car in square feet
V = speed in miles per hour

*Factors are for freight cars; other values are substituted for passenger cars and locomotives.

In the formula, the expression $1.3 + \frac{29}{W}$ represents journal resistance; $0.045V$ represents flange resistance; and $\frac{0.0005\ AV^2}{Wn}$ represents air resistance.

As an example, the rolling resistance (R) of a 40-ton (W=10, n=4) box car of 80 square feet cross section (A=80) at 10 mph (V=10) would be:

$$R = 1.3 + \frac{29}{10} + (0.045 \times 10) + \frac{(0.0005 \times 80 \times 10^2)}{(10 \times 4)} = 4.75 \text{ lbs./ton.}$$

(The formula is not applicable to starting resistance, i.e., to speeds of 0 mph)

GRADE RESISTANCE

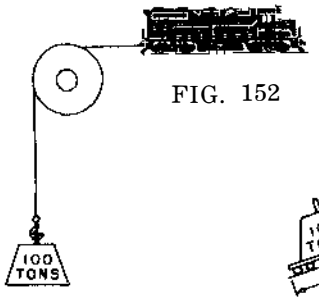


FIG. 152

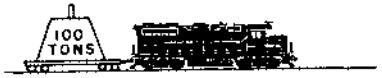


FIG. 153

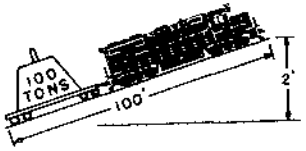


FIG. 154

Considering only the resistance of the load due to gravity . . .

In Fig. 152, for every foot it travels, the load also rises one foot. The ratio between rise and distance traveled, being 1:1, establishes this as a

100 percent grade. In such a case, the resistance of the load is apparently equal to its weight, and may be expressed either as 100 tons or as 2000 lbs./ton.

. . . in Fig. 153, representing level track operation, the ratio between rise and distance traveled is 0:1, hence the grade is 0 percent, and the resistance of the load due to gravity 0 tons or 0 lbs./ton.

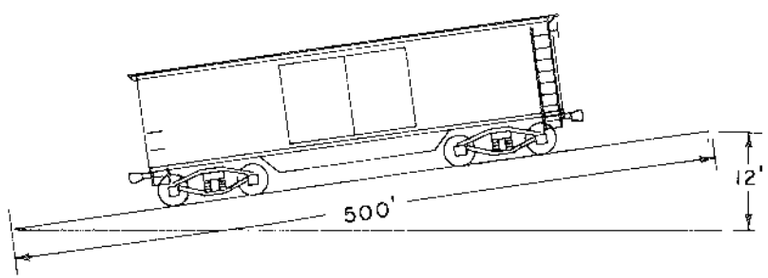
In Fig. 154 the ratio between rise and travel is 2:100, or 2 percent. The resistance of the load due to gravity is 2 percent of its weight or 2 tons (4000 pounds). Resistance expressed in pounds per ton is equal to:

$$\frac{4000 \text{ lb.}}{100 \text{ Tons}} = \frac{40 \text{ lb.}}{\text{Ton}}$$

Expressed more conveniently, resistance equals $\frac{\text{rise} \times 100}{\text{travel}} \times 20$ lb./ton,

or, is equal to 20 pounds/ton for each percent of grade (or .379 lb./ton for each foot of rise per mile).

Grade resistance, expressed in pounds per ton, is independent of and unrelated to train speed. It is always equal to 20 pounds/ton for each percent of grade.



In the sketch above, grade resistance of the car is equal to 48 pounds/ton, derived thus:

$$\frac{\text{Rise in elevation} \times 100}{\text{Distance traveled}} \times 20 \text{ lb./Ton} = \frac{1200}{500} \times 20 \text{ lbs./Ton} = 48 \text{ lb./ton}$$

If the grade is not "compensated" i.e., if the physical grade is not reduced to negate the effect of curvature upon it), allowance must be made for track curvature. Each degree of curvature adds one pound per ton to grade resistance, or is the equivalent of a .05 percent grade. Thus, in the

above example, if there were a three degree curve over the *entire* 500 foot section, the allowance for the effect of curvature to be added to the basic 2.4 percent grade would be:

3 degrees x .05 percent = .15 percent

And the effective (total) grade resistance would be: (2.4% + .15%) x 20 lbs./Ton = 2.55% x 20 lb./Ton = 51.0 lbs./Ton.

CURVE RESISTANCE

Because the wheels of railroad rolling stock are fixed to, and therefore rotate with, their axles in rounding a curve there is a tendency for the wheel following the inside track to be skidded — or for the outside wheel to spin. Whether one or the other occurs or whether the tendency is overcome by lateral movement of the axle within its journals, friction (resistance) is created. The "sharper" the curve, the greater this resistance becomes.

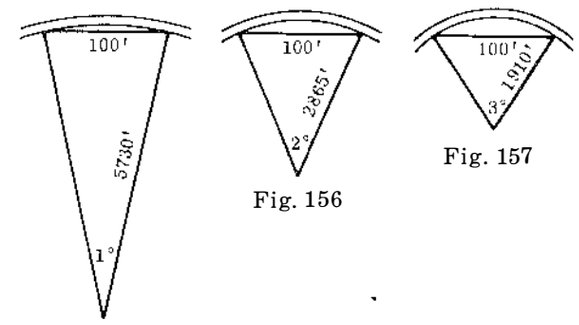
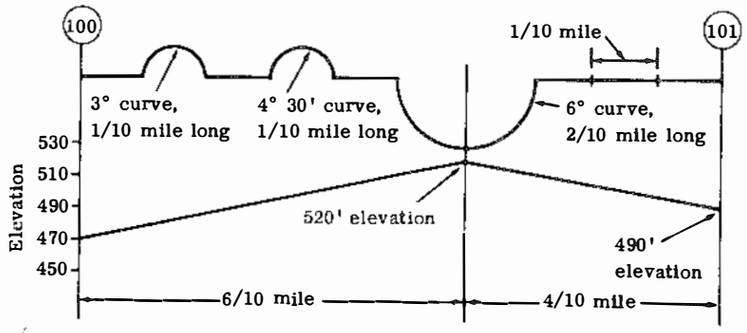


Fig. 155 Fig. 156 Fig. 157

By definition, a one degree curve is a curve, a 100 ft. chord of which determines a one degree central angle (Fig. 155). It happens that such a curve has a radius of 5730 feet. Given the degree of curvature, radius can be determined by dividing 5730 feet by the degree of curvature. Thus two and three degree curves (Figs. 156 & 157) have respective radii of $\frac{5730 \text{ ft.}}{2}$ and $\frac{5730 \text{ ft.}}{3}$, or 2865 and 1910 feet.

The effect of varying degrees of curvature on train resistance has been determined by test, and most simply stated, indicates that one degree of curvature offers the same resistance to train movement as a 0.05 percent grade, i.e., 1 pound/ton (0.05 x 20) for each degree of curvature.

ALLOWANCE FOR CURVATURE



The method for adjusting gradient calculations to allow for the effect of the resistance added by track curvature can be illustrated with the above representation of a one-mile section of track chart and profile:

1. *Determination of gradient*

   From milepost 100 to location 100.6:

$$\frac{\text{Rise x 100}}{\text{Distance}} = \frac{(520\text{ ft.} - 470\text{ ft.}) \text{ x } 100}{6\text{ mi. x } 5280\text{ ft.}} = \frac{5000\text{ ft.}}{3168\text{ ft.}} = 1.58\%$$

2. *Determination of average curvature*

   From milepost 100 to location 100.6:

$$\text{Avg. curve} = \frac{(3^\circ \text{ x } .1\text{ mi.}) + (4.5^\circ \text{ x } .1\text{ mi.}) + (6 \text{ x } .1\text{ mi.})}{.6\text{ mi}}$$

$$\frac{1.35^\circ\text{ mi}}{.6\text{ mi}} = 2.25^\circ$$

3. *Determination of grade equivalent of 2.25° curve*

   Grade equivalent = 2.25° x 0.05 = .1125%

4. *Determination of effective grade*

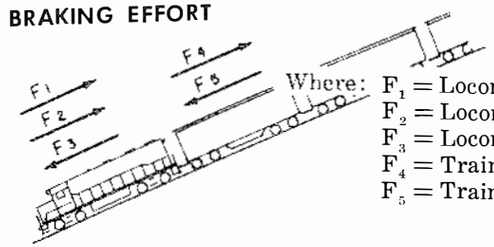
   From milepost 100 to location 100.6:

   Effective grade = Actual Grade + Grade Equivalent = 1.58% + .1125% = 1.69%.

   (Descending, the effective grade = —1.58% + .1125% = —1.47%

SECTION 11. TRAIN AND LOCOMOTIVE PERFORMANCE

BRAKING EFFORT



Where: F_1 = Locomotive braking effort
F_2 = Locomotive rolling resistance
F_3 = Locomotive grade force
F_4 = Train rolling resistance
F_5 = Train grade force,

$$F_1 + F_2 + F_4 = F_3 + F_5, \text{ or, } F_1 = F_3 - F_2 + F_5 - F_4$$

Thus the braking effort required to hold a given train to a given speed on a given grade can be calculated according to formula.

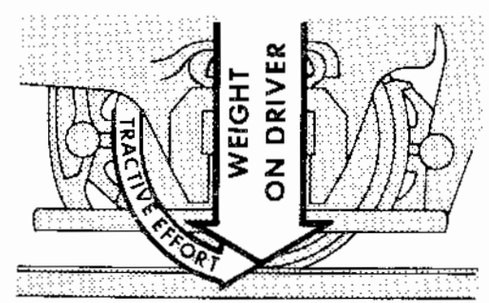
For example, what braking effort (F_1) is required to hold a 2000-ton train and 130-ton locomotive to 15 mph on a 2 percent grade?

F_2 lb = 480*
F_3 lb = 130 Ton x 20 lb/Ton/% x 2% = 5200
F_4 lb = 2000 Ton x 4.3 lb/Ton* = 8600
F_5 lb = 2000 Ton x 20 lb/Ton/% x 2% = 80000
F_1 lb = 5200 — 480 + 80000 — 8600 = 76120

The braking effort required to satisfy any given set of operating conditions can be determined in this way. Similarly, of course, given the available braking capacity, the maximum train size can be established. It can be shown that greater braking effort would be required for a 2000-ton train made up of heavier cars. These relationships are unaffected by the presence or absence of dynamic brakes on the locomotive.

* from rolling resistance tables for 130-ton locomotive and 50-ton car

ADHESION



Unless the ratio of weight on drivers to tractive effort is at least 4:1, chances are good that the wheel will slip.

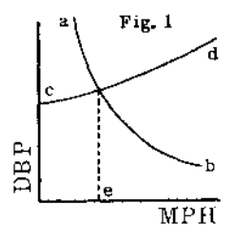
Stated conversely, when "adhesion," (or the ratio of tractive effort to weight on drivers) exceeds 25%, chances are good that the wheel will slip.

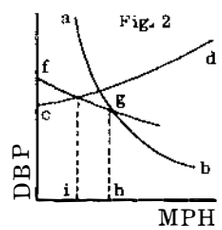
The amount of tractive effort that can be *developed* is wholly independent of locomotive weight.

Nor does locomotive weight by itself affect the percent of adhesion that will be reached before slipping occurs. This is a function solely of rail conditions.

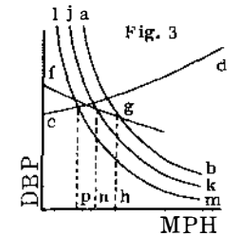
With a given set of rail conditions which limits adhesion to, say 20%, any and all locomotives—regardless of weight or horsepower—will slip whenever their operation calls for tractive effort exceeding 20% of the weight on drivers. Thus under conditions that will cause a four axle locomotive to slip at 20% adhesion, a six-axle locomotive will slip at the same 20% adhesion level. The six-axle unit's added weight increases the amount of tractive effort *usable* under given conditions, but does not increase—or in any way affect—the available adhesion. The six motor unit is no more capable of 30% adhesion than the four motor unit.

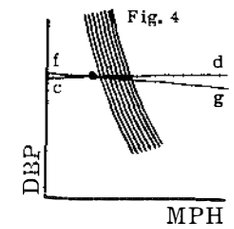
REDUCING THROTTLE to correct a wheel slip condition





1. Let ab in Fig. 1 represent a hypothetical locomotive's full throttle available drawbar pull, and cd total train resistance. With no adhesion limit, a balance speed will be attained at e mph.
2. Let fg in Fig. 2 represent the limit of usable adhesion. Then fgb becomes the locomotive's practical DBP curve. At any speed below h mph slipping will occur in full throttle. Operation can be sustained only at a speed where available DBP does not exceed usable DBP and where train resistance does not exceed available DBP. Apparently full throttle operation does not satisfy these conditions. Also it is apparent that it would be impossible to satisfy the conditions at any speed above i mph.

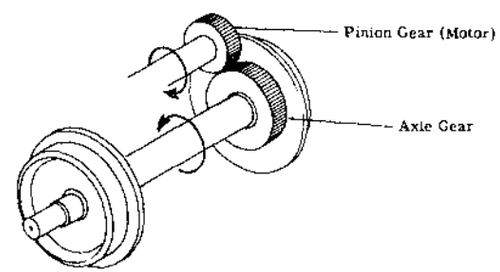




3. Let jk and lm in Fig. 3 represent available DBP for successive reduced throttle operations. The first throttle reduction (jk) will still produce slipping, but at a higher DBP output and lower speed (n mph) than full throttle. A second throttle reduction (lm) will sustain a balance speed at p mph, since at that speed DBP and train resistance are equal and available DBP does not exceed usable DBP.
4. The train resistance curve (cd) and adhesion limit curve (fg) should more realistically approximate horizontal lines, as in Fig. 4. Obviously conditions might be such that no number of throttle reductions can correct a wheel slip condition even though at some speed usable DBP exceeds train resistance.

GEAR RATIOS

A 62-tooth axle gear—15-tooth pinion gear comprises a 62:15 gear ratio. For every 62 revolutions of the motor armature, the driving wheel makes 15 revolutions.



Given constant horsepower, the ratio between the driving gear and the driven gear has no effect on the tractive effort developed at a given speed. Thus if a given locomotive with a 62:15 gear ratio delivers 35,000

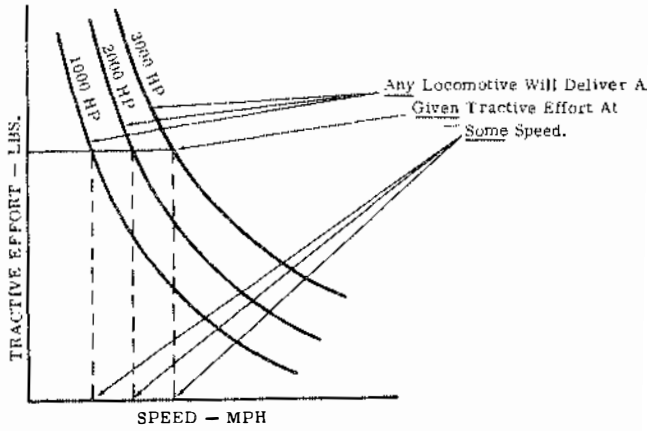
pounds of tractive effort at 20 mph, the same locomotive with a 60:17 or a 59:18 ratio would deliver the same 35,000 pounds at 20 mph.

And since at full load, a given current will produce a corresponding armature speed regardless of gear ratio, the effect of changing gear ratios is to change the train speed at which a given current or armature speed obtains.

Therefore:

1. Increasing the gear ratio (e.g. going from 60:17 to 62:15) reduces the minimum speed (hence increases tonnage) at which a given locomotive can operate without heat damage to its motors.
2. Decreasing the ratio increases the maximum speed at which a given locomotive can operate without mechanical damage to its motors.

HORSEPOWER AND TONNAGE



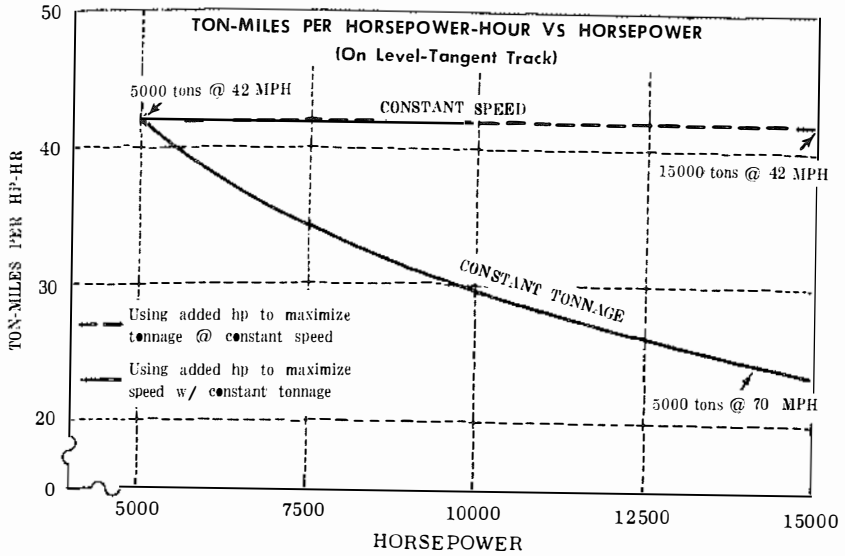
If the 1000-horsepower locomotive slips at the indicated tractive effort output, so too will the 2000 and 3000-horsepower units, provided that all three have the same weight on drivers.

And since tractive effort (after allowance for locomotive resistance) is the force actually pulling the train, the 1000-horsepower unit can pull as much tonnage as the larger units, although at a lower speed.

Similarly, locomotives identical except for horsepower outputs will reach their motor ratings at the same tractive effort output, but at different speeds.

Horsepower increases alone cannot increase a locomotive tonnage rating.

INCREASED HORSEPOWER, its effect on speed and tonnage



1. A 5000-hp locomotive can pull 5000 tons at 42 mph on level tangent track.
2. Three such locomotives (15,000 hp) can either . . .
   a. . . . pull 15,000 tons (three times as much) at the same 42 mph speed, or
   b. . . . pull the same 5000 tons at 70 mph (the equivalent of a 66% speed (increase) in return for a 200% horsepower increase.
3. It would require 45,000 horsepower to pull the 15,000-ton train at 70 mph.

For a given horsepower investment, tonnage offers a better return (measured in performance) than do Miles-Per-Hour.

MIXED CONSIST OPERATIONS

Operation of other than identical units in a single locomotive consist under common control usually creates no particular problem except at the upper and lower speed extremes. Every such consist will have its "weak

unit," and tonnages and speeds for the consist must be tailored to protect that unit.

1. In *drag service*, the "weak unit" is the one whose adhesion or thermal limit is reached at the *highest* speed. Since therefore the minimum speed of each unit in the consist becomes that of the "weak unit," the maximum tonnage assignable each unit becomes that which it can pull at that speed, not that which each can pull at its own minimum speed. (It is quite possible for a three-unit consist of six-motor units to have a higher tonnage rating than a consist made up of the same three units and an added four-motor unit, since in effect all units become four-motor units.)
   In *pusher operations*, where the two locomotive consists are under separate control, these generalizations do not necessarily apply.
2. In *high speed* service, the "weak unit" is the one with the *lowest* allowable maximum speed, and the allowable top speed of the consist becomes that of the "weak unit." The horsepower gained from the addition of a "low speed" unit to a "high speed" consist is useful only at speeds below its own maximum.

HORSEPOWER AND TRACTIVE EFFORT

A diesel locomotive are related as expressed in the formulae:

$$\text{Horsepower} = \frac{\text{Tractive Effort (lbs.)} \times \text{Speed (mph)}}{308^*}$$

$$\text{Tractive Effort} = \frac{\text{Horsepower} \times 308^*}{\text{Speed}}$$

*Derived from 375 pound-miles per hour (1 horsepower) x 82% transmission efficiency

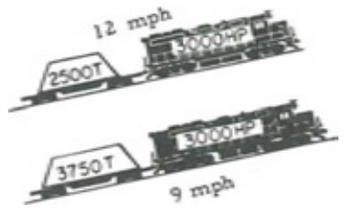
Since train resistances do not vary significantly with speed in the range between 8 and 15 miles per hour, the above formulae can be used as the basis for performance approximations within that range. Such approximations assume that regardless of speed the rolling resistance of an "average" 40-60 ton boxcar is 4.0 pounds per ton.

Example: Determine the horsepower required to lift a 1750-ton train (including locomotive weight) over a 2.0% grade at 12 miles per hour.

1. TE = Train Resistance (including locomotive), and therefore,
2. TE = 1750 Tons (4.0 lbs./Tons + (20 lbs/Tons/% x 2%*)
   = 1750 Tons x 44 lbs./Tons = 77000 lbs.
3. $\text{Horsepower} = \frac{77000 \text{ lbs.} \times 12 \text{ mph}}{308 \text{ lb.—mph}} = 3000$

Grade resistance = 20 lbs./ton for each percent of grade.

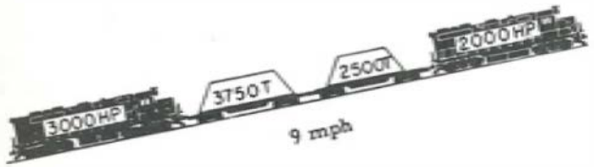
PUSHER LOCOMOTIVES



Say that the adhesion ratings of two locomotives on a given grade compare as follows:

1. 3000-hp 4 motor unit: 2500 Tons @ 12 mph
2. 3000-hp 6 motor unit: 3750 Tons @ 9 mph

The two units in multiple would have to maintain a 12 mph speed, hence would have a combined tonnage rating of 5000 tons—i.e., the six-motor unit loses its advantage when in consist with a four-motor unit. Nor is locomotive capability improved by placing one of the units on the rear as a pusher. The advantage of a pusher as such lies only in the reduced likelihood of drawbar breakage with a given train, and in the ease with which it can be separated from a train when no longer needed.

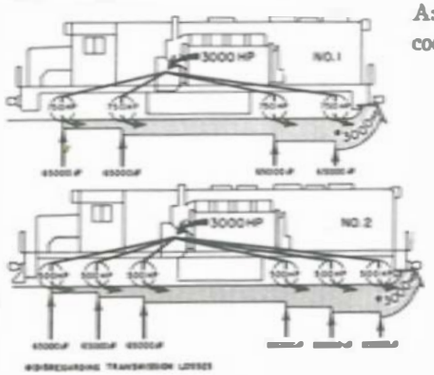


By separating control of the two units, however, it becomes possible for each to handle its rated tonnage in a single train. While it is not possible for the four-motor unit to deliver 3000 horsepower at 9 mph without wheel slip, it can handle its 2500 rated tons at that speed provided its horsepower output is reduced. At the same time, with its full horsepower

maintained, the six-motor unit will retain its 3750-ton rating at the 9 mph speed.

The effect is to distribute the total train weight between the two units in proportion to their respective horsepower outputs. It is because control is separate, however, and not because of the location of the units in the train that this is possible. Note that the price of this technique to maximize tonnage is reduced train speed.

4 MOTORS, 6 MOTORS?



Assume two hypothetical locomotives compare as follows: e as follows:

	hp	Motors	Weight
No. 1	3000	4	260,000
No. 2	3000	6	390,000

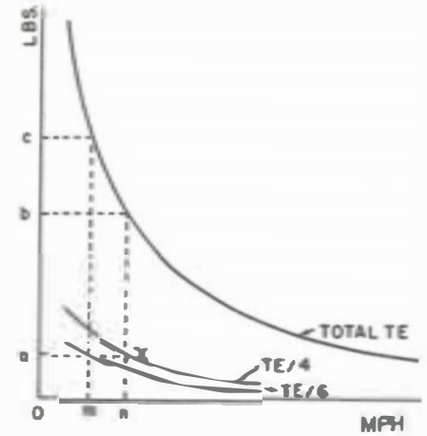
Then:

	hp Motor	Weight/Axle
No. 1	750	65,000
No. 2	500	65,000

Now since both are 3000 hp units, and since T.E. $= \frac{\text{hp} \times 308}{\text{Speed}}$, the speed—TE curves of the two units may be considered identical and may be represented by the Total TE curve at the left. The Speed—TE curves for *each* motor of No. 1 and No. 2 units are shown as TE/4 and TE/6 respectively.

Then, if adhesion is limited to, say, 20%, each axle can deliver 13,000 pounds of TE before slipping is induced. Let ax represent the adhesion limit per axle. Apparently No. 1 unit reaches this limit at a speed 1½ times greater than No. 2 unit. And therefore, since, again TE $= \frac{\text{hp} \times 308}{\text{speed}}$, the No. 1 unit can deliver only 2/3 as much *total* TE without slipping. Note that the same comparison would be true if ax represented a 13,000 pound per motor *thermal* limit.

Note also that if less than b pounds of *total* tractive effort are required, No. 2 unit has no advantage since at the resulting speed the tractive effort requirement per axle would be less than the ax limit in



both cases, and that above c pounds, neither unit can be operated. It is only in the speed range between m and n mph that a six-motor unit has any advantage.
TE = Total tractive effort.

ADJUSTED TONNAGE RATINGS

Car Weight - Tons		20	50	80
Resistance - 1% grade 10 mph		27.5 lbs./T.	24.0 lbs./T.	22.9 lbs./T
Rating	Tons	2800 (R_1)	3200 (R_2)	3360 (R_3)
	Cars	140 (N_1)	64 (N_2)	42 (N_3)

Given the above resistance data, tonnage ratings for a hypothetical locomotive might be calculated as shown. Apparently, no single rating can be used as a basis for assigning maximum tonnage where car sizes vary from train to train or within individual trains. A system has therefore been devised (and is in use on some railroads) which makes it possible to express tonnage ratings without regard to the sizes of different cars comprising a train. Such ratings are "adjusted tonnage ratings," and are based on the formula.

Adjusted Tonnage Ratings = Actual Tonnage ÷ (Car Factor x No. of Cars), where the "car factor," in turn, is derived thus:

$$\text{Car Factor} = \frac{R_2 - R_1}{N_1 - N_2} = \frac{3200 - 2800}{140 - 64} = 5.26$$

Then Adjusted Tonnage = 3200 + (5.26 x 64) = 2800 + (5.26 x 140) = 3537

Note, however, that the adjustment is an approximation only. To illustrate:

1. Using data for 20 Ton and 80 Ton cars (instead of 20 and 50 Ton cars) in the car factor formula would produce a different car factor and therefore a different adjusted tonnage rating.
2. Applying the 5.26 factor to 80 Ton cars gives a 3581 Ton adjusted rating.

The steeper the grade, the smaller the car factor, since rolling resistance becomes a relatively less important part of total resistance.

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